PB-226 422

URBAN AEROSOL: COUNT SIZE RELATED TO METEOROLOGIC DATA

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November 1969

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Final Report

Urban Aerosol: Count Size Related to Meteorologic Data

by

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Research Grant AP 00453-03

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November, 1969

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CHAPTER 1

INTRODUCTION

The concentration and size distribution of particles dispersed in the atmosphere are major parameters in the study, evaluation and control of the aeroenvironment. In addition, relating these parameters to existing meteorological conditions are of prime importance in studying and understanding the behavior of the particles. Particle and meteorological parameters have been singly measured and investigated for a number of years but seldom have they been studied jointly as existing instrumentation, for the measurement of particle size and concentration, were not readily adapted to continuous monitoring of atmospheric particles. Available instrumentation has generally been size specific, incapable of sampling at high enough rates to permit time dependent measurements and the resulting data were obtained only after lengthy analysis of the collected material.

In the last several years there have become available a number of particle sizing and counting instruments which are still size specific but capable of larger sampling rates and functioning in a manner whereby size-number data are more readily obtained. Specific instruments possessing these characteristics are light scattering optical particle counters, electrical particle counters, and nuclei counters. Light scattering optical particle counters have been described and studied by a number of investigators (1-8). The response of these instruments has been steadily perfected and sampling rates of 0.1 cubic feet per minute while detecting and counting particles from 0.3 micron and larger in size are now possible. Whitby, Jorden, and Peterson (9) developed an electrical particle counter capable of providing current flow data reducible to particle number in specific size ranges from 0.01 to 0.5 micron particle diameter. Skala (10) and Rich (11) describe the principle and use of condensation nuclei counters to determine the presence of particles in the size range from approximately 0.002 to from p. 1

0.1 micron diameter.

The primary objective of this study was to demonstrate that three particle sizing and counting instruments could be combined to form a system capable of automatically monitoring a broad spectrum particle size distribution.

A General Electric Condensation Nuclei Counter, a University of Minnesota Electrical Particle Counter and Royco Model No. 220 Light Scattering Particle Counter were used in the development of the system. As developed, the broad size spectrum particle counting and sizing system was capable of sizing and counting particles within the 0.002 to 10 micron diameter size on an automatic semi-continuous basis.

The particle counting and sizing system was installed at a local television tower site and operated in conjunction with meteorological sensing instruments, mass loading sensors and gas and biological samplers. The resulting array of data were used to investigate particle behavior during various meteorological conditions, to test the accuracy of existing mathematical models pertaining to particle size distribution, to relate particle number and mass phenomena and to determine specific gas and micro flora concentration of the ambient atmosphere at the monitoring location. The data for each subject area of investigation are not conclusive evidence of behavior during each respective phenomena or event, but they do suggest areas where additional research and study are needed.

The system has proven to be effective in providing information in this area of investigation and has been used as the prime source of data for several Ph.D. research projects. With slight modifications, the system could readily be used to more accurately study particle filtration theories; optical characteristics; coagulation, settling and diffusion rates and physiological responses. The meteorological-time data are essential in the determination of sedimentation, coagulation and diffusion phenomena. In addition, the accumulation of time dependent aerosol

over →

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and meteorological parameter data should provide insight into the investigation of weather variations and exposure levels which may be significant in detecting and explaining physiological responses.

Chapter II

HISTORY OF ATMOSPHERIC PARTICLE STUDIES

A. Experimental Studies

Junge (12) was the first to measure and report on atmospheric aerosol concentrations and particle number-size distributions. He combined an impactor and an apparatus which measured ion mobility to analyze particles suspended in the atmosphere of Frankfurt and the Zugspitze Mountains in Germany. Particles in the range of 1.0 to 40 microns in diameter were collected with the impactor and enumerated in size groups with a light microscope. The ion mobility measurements were used to obtain information on the particles present in the smaller size range. An arbitrary upper and lower particle diameter detection limit was set at 0.3 and 0.006 micron respectively for the ion measurements recorded. He reported that the number concentration measurements in the range from 0.16 to 1.0 micron were of questionable accuracy. Cartwright *et al*. (13) obtained particle samples from the atmosphere with a thermal precipitator and used an electron microscope to count and size the number of particles collected in the diameter size range from 0.06 to 1.8 micron. Samples were collected from country and industrial locations near Buxton and Sheffield, England. Although lacking certain sizes, Cartwright's data were inclusive of the number of particles present between the upper limit of ion measurement and the lower limit of resolution of optical measurements. This was a particle size range in the atmosphere which previously had not been investigated. Twomey and Severyne (14) perfected a system of diffusion batteries and a condensation nuclei counter to count particles within the nuclei range.

Friedlander *et al*. (15) measured the atmospheric particle number-size distribution around Baltimore, Maryland by using a four stage impactor and a novel rotating disk arrangement which collected particles in the sub-impactor size range. Particles were sized and counted by electron and light microscopy but particles in the size range of 0.1 to 0.4 micron diameter were not efficiently collected by either the impactor or the rotating disk.

Hilst (16) was the first investigator to measure and observe changes in the particle number-size distribution as a function of height. However, his measurements were limited to collecting atmospheric samples with a cascade impactor and particles smaller than 0.9 micron were not retained on the impactor plates. Whitby et al. (9) combined an optical and an electrical particle counter with a condensation nuclei counter to measure indoor and outside particle contamination. The particles present were sized and grouped in diameter size increments from 0.002 to approximately 10 microns. The outdoor measurements by Whitby and Clark (17) were obtained at the University of Minnesota. By sampling from a second floor window of a four-story building which opened to a court yard, their results appear to be the first recorded in an attempt to characterize the number-size distributions with measured weather parameters. Sholtes and Emery (18) report on particle number concentration measurements obtained at different elevations above Jacksonville, Florida. By using a weather balloon, a rotorod was raised to various heights and operated for specific time periods. Sholtes and Emery also measured the vertical temperature distribution and noted the horizontal wind speed.

Magill (19) and Kratel (20) have determined particle size distribution of aerosols in the free atmosphere with automatic Royco particle counting instruments. The number and diameter of aerosol particles in 15 measuring ranges between 0.3 and 10 microns and an additional range which comprised all particles above 10 microns was determined. Magill's results are reported as an average particle number-size distribution determined over one year in New York, New York and over a period of several weeks from the environment south of San Francisco, California. Kratel's measurements were taken in large and small cities, industrial concentration areas and resort centers. Specific areas of investigation in Germany were

Stuttgart, Neckarsulm, Leonberg, Biberach, Essen, Gerslingen/Steige, Sauerland, Munich, Upper Bavaria, Karlsruhe and the Black Forest.

All of the aforementioned measurements were initial attempts to establish, on the basis of particle number, a meaning to the words "pure" and polluted air. In each study, the lack of automatic time-dependent instrumentation is evident. A few studies have provided data characteristic of the complete atmospheric particle size spectrum and the investigations have generally resulted in averaged concentrations measured over a period of time. The simultaneous measurement of meteorological parameters and particle data is noticeably lacking. This information is necessary in determining the variation in particle concentration and in estimating the pollution potential of the aero-environment.

B. Previous Results and Theoretical Consideration

Atmospheric aerosol size distribution data are generally presented as a plot of dN/d(log r) per cm^3 versus the radius (r) in microns on a log-log scale. N is the number of particles. Particle size based on the diameter size can also be used in place of the radius. Presentation of data in this manner provides an indication of the size distribution and, in addition, the total number of particles per cm^3, ΔN, within any size interval, $\Delta(\log r)$ can readily be determined from the plot. The use of logarithmic scales is justified on the basis of the range of particle sizes and numbers normally present in the average outdoor environment.

The results obtained by Junge (12) in Frankfurt, Germany and by Friedlander and Pasceri (21) in Baltimore, Maryland are shown in Figure 1. The distribution by Junge represents the averages of from 11 to 25 individual measurements. The data of Twomey and Severynse (14) closely follows that of Junge with the exception of an apparent second mode in the size distribution at about 0.007 microns. A number-size distribution determined by Cartwright *et al.* (13) for the atmosphere of Sheffield, England and one by Whitby and Clark (17) for the atmosphere of Minneapolis, Minnesota are shown in Figure 2. The distributed number-size data collected by Magill (19) for the respective atmospheric conditions in New York City and Southern San Francisco and by Kratel (20) for Stuttgard and Geislinger/Steige, Germany are plotted in Figure 3.

Hilst (16) sampled the atmosphere at various heights and obtained particle number-size distributions but his results only include particles larger than 0.9 micron (up to 500 microns). Particles of this size are in the settleable size range and are generally present as a result of disintegration of matter or the coagulation of smaller particles. Hilst comments that there appears to be little doubt that airborne dust concentrations decrease rapidly with height in the vicinity of ground surfaces. His comments are supported by Chepil and Milne (22) as they found that 93 percent of soil-eroded particles are transported into the atmosphere over an open field in a layer between the surface and a height of one foot.

During stable conditions, Sholtes and Emery (18) found that the concentration of all measured particles (greater than two microns) exhibits a stratum of maximum number around the 200-foot elevation. He reports a rapid increase in particle concentration from ground level up to the 200-foot level. In general, this layer of stratification corresponds to the physical stack height of most local sources of pollution in the Jacksonville area.

The plots of data points shown in Figures 1, 2, and 3 are time-averaged number-size distributions measured at different areas of the world. Order of magnitude differences in concentration are evident but the slopes of the concentration versus radius (or diameter) curve on a log-log basis are about the same for the size spectrum of particles larger than about 0.1 micron in radius. The similarity of such distribution functions measured at different times and places was first noted by Junge (12, 23). Consequently, he proposed that the recurring

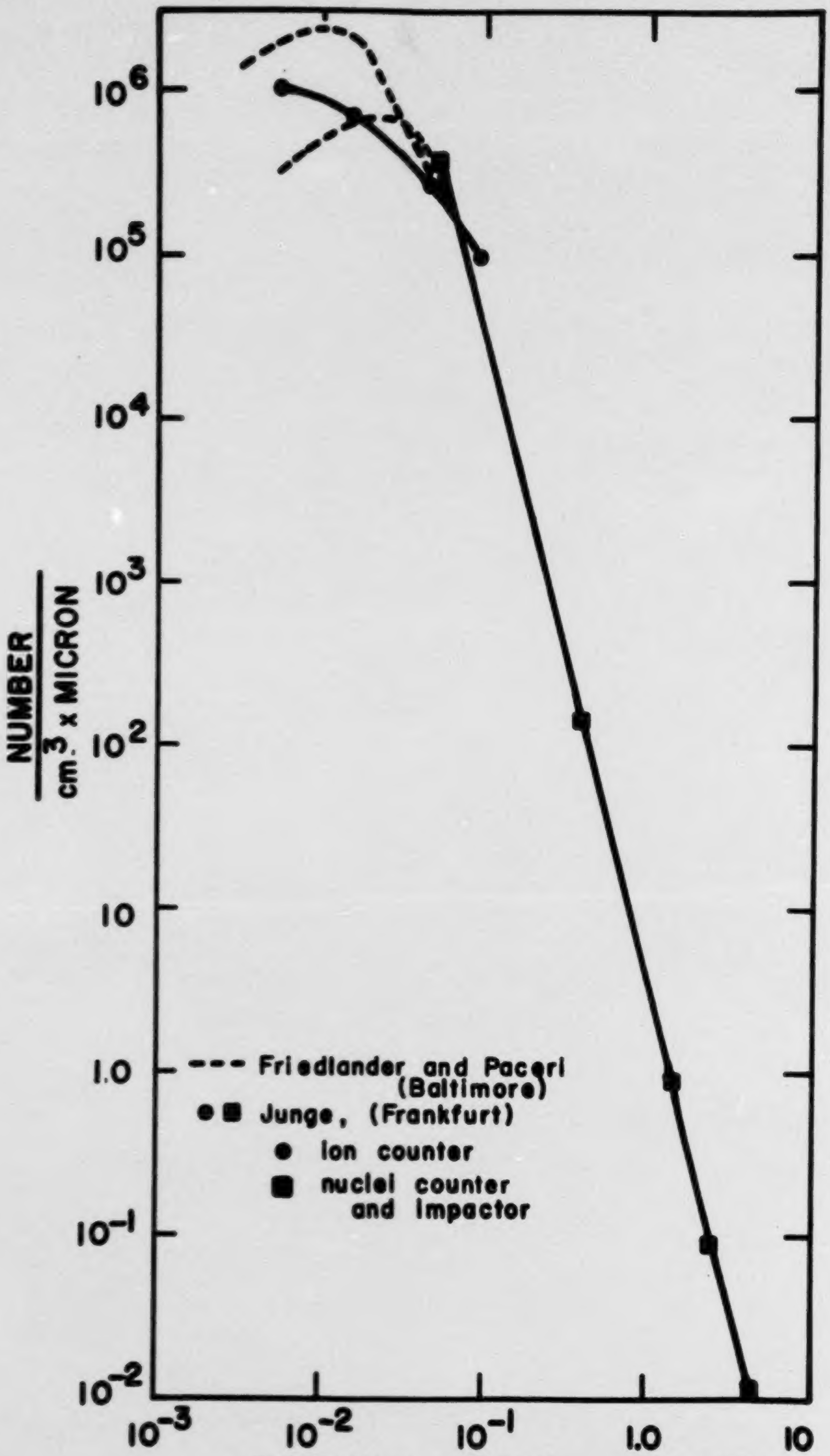


Figure 1. Particle number-size distributions for the atmospheric conditions of Frankfurt, Germany and Baltimore, Maryland. (Whitby and Clark, 1966)

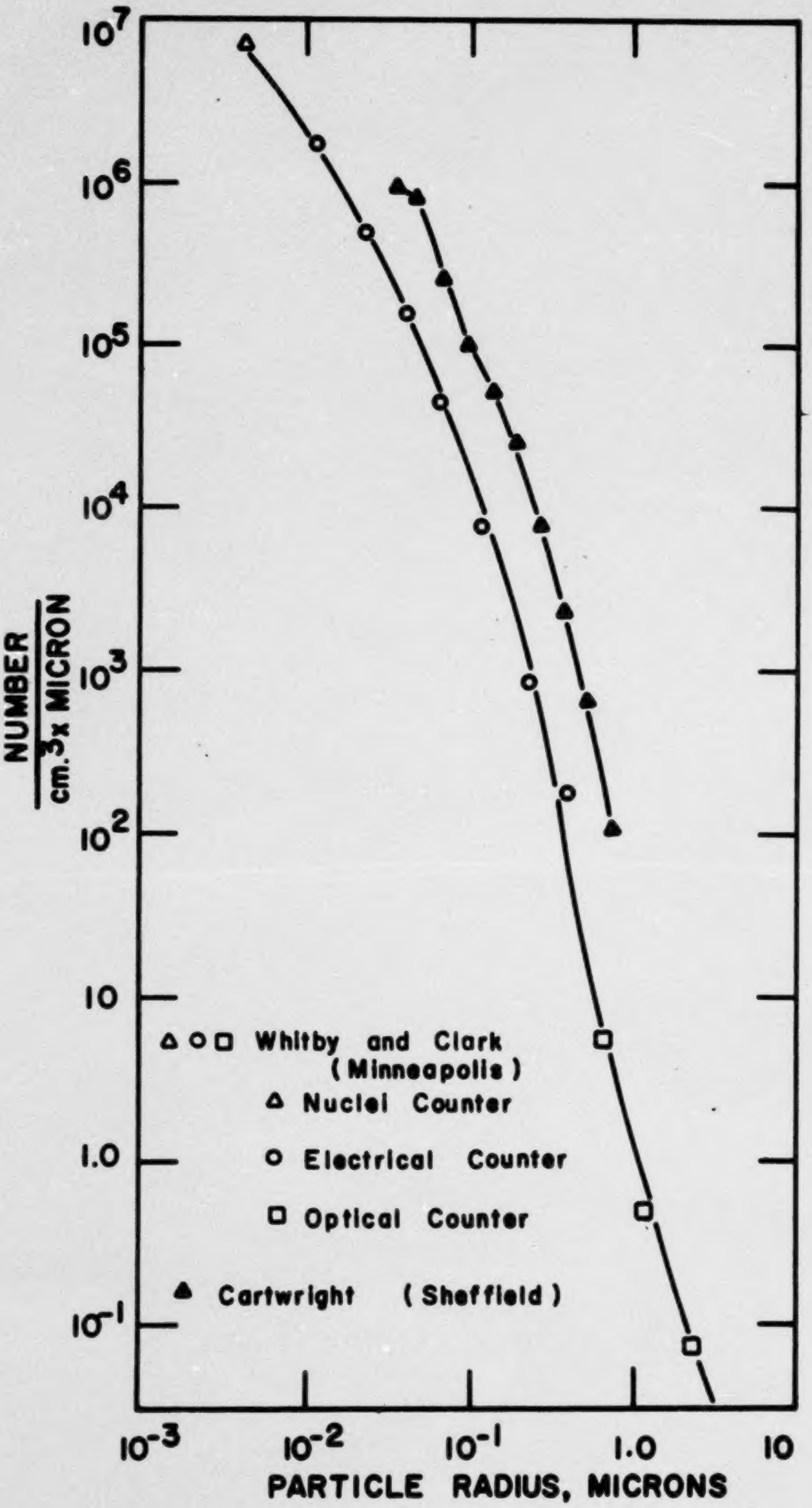
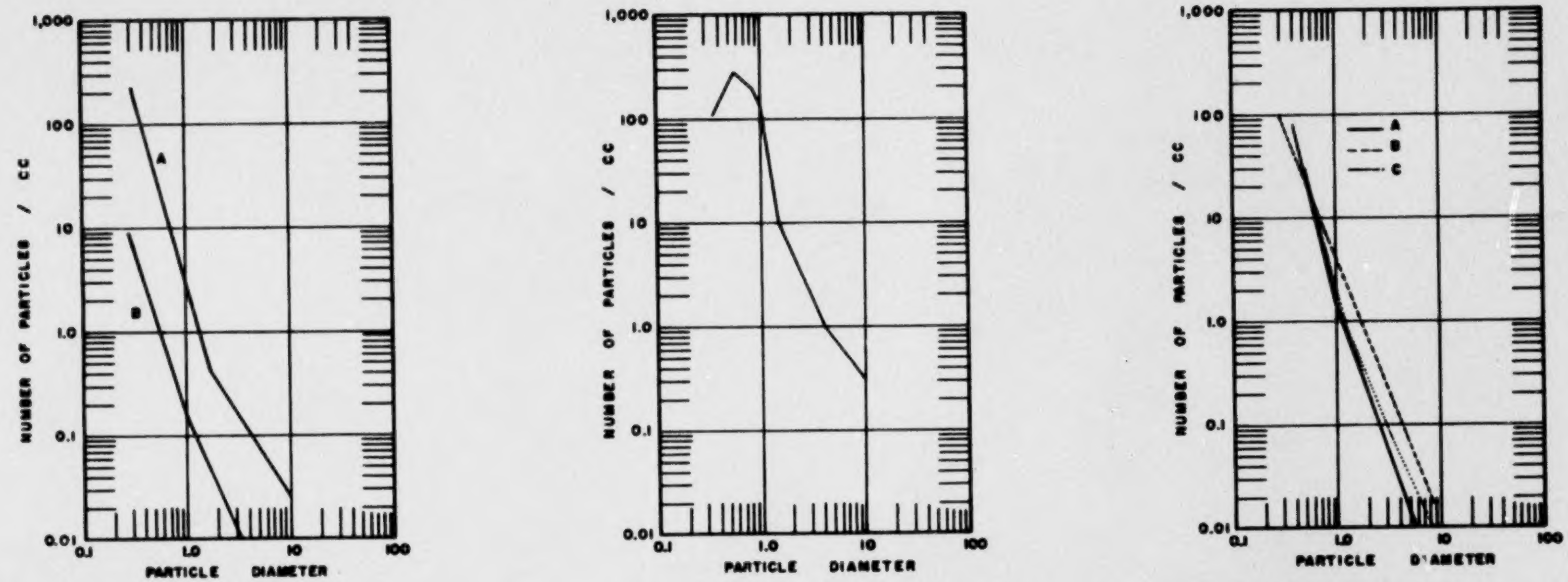


Figure 2. Atmospheric particle number-size distributions for Sheffield, England and Minneapolis, Minnesota. (Whitby and Clark, 1966)



ATMOSPHERIC AEROSOL IN STUTTGART
A CITY CENTER, AUGUST 1964, HOT AND DRY SUMMER DAY, LULL
B. CITY CENTER, SPRING 1964, HUMID DAY LIGHT WEST WIND

ATMOSPHERIC AEROSOL IN GEISLINGEN/STEIGE AT THE EAST SIDE OF A FACTORY

NATURAL ATMOSPHERIC AEROSOL
A. NEW YORK (avg. - year)
B. PROPOSED BY JUNGE
C. SOUTH OF SAN FRANCISCO (avg. - weeks)

Figure 3. Atmospheric particle number-size distributions for Stuttgart and Geislingen/Steige, Germany and for New York City and South San Francisco. (Kratel, 1965)

particle number-size distribution of large and giant particles could be appropriately expressed by equation 1:

$$dN/d(\log r) = \text{constant} \times r^{-3} \qquad (1)$$

In this equation, N is the particle concentration and r is the particle radius size. As a consequence of equation 1, it follows that the size distribution function n(r) is proportional to r^{-4}.

A number of experimental and theoretical investigations have been performed to establish and define this regularity in heterogeneous particle number-size distributions. In 1957, Junge (24) offered an explanation based on the mixing of rather special aerosols of specific particle number-size distributions. Since this first tentative explanation, Friedlander (25, 26, 27) proposed that the similarity can be explained on the basis of both dimensional considerations and a similarity or "self preserving" solution to kinetic equations which result in the size distribution function. Hidy (28), Hidy and Lilly (29) and Friedlander and Wang (30) have further studied Friedlander's original self preserving solution to the kinetic equations with numerous numerical methods programmed for computer analysis. Swift and Friedlander (31) reported on experimental studies conducted to investigate the validity of the theoretical considerations.

Friedlander's explanation of distribution regularity is actually based on the existence of dynamic equilibrium between particle production, diffusion, coagulation and sedimentation. The explanation is not dependent upon the initial size spectra or the proportion of mixing of special aerosols as suggested by Junge. However, the equilibrium is characterized by defining the processes of particle behavior within various ranges of the particle size spectrum. Critical to this analysis is the consideration of an incremental volume of air which is not directly affected by particulate emissions from a distinct source. If the volume of air is of sufficient size so as to contain a large number of particles but small enough to avoid particle concentration differences within the volume, it can be assumed that particles contained in a specific size range, (dr), are lost or gained only by diffusion, coagulation or sedimentation. Small particles (less than 0.1 micron) are transported to the volume by diffusion and the larger particles are lost be sedimentation. Particles within the size range not generally influenced by diffusion or sedimentation are also changed as there is coalescence among small particles and attachment to larger ones. Particle coagulation results from Brownian movement and other particle motion within the elemental volume. Since the similarity characteristics have been observed only for the particle size spectrum greater than approximately 0.1 micron, diffusion phenomena are generally not considered important. Particles less than 0.1 micron do enter the space through diffusion and are a factor in maintaining the coagulation process, but the mass of these particles is quite insignificant when compared to the spectrum of larger particles. Therefore, in Friedlander's explanation, it is assumed that a statistically steady state is attained when the volumetric rate of matter entering the volume by coagulation of smaller particles from outside the space is equal to the rate of loss by sedimentation.

With this explanation it is also assumed that whenever an excess of small particles enters the volume, the rate of coagulation temporarily becomes greater. This produces a larger number of settleable particles and sedimentation rates increase. When coagulation and sedimentation processes equalize, the distribution is in a state of dynamic equilibrium. The effect of this equilibrium is shown in Figure 4 where coagulation and sedimentation characteristics have been applied to the average airborne particle mass-size frequency distribution as determined in the ASHAE Dust Survey (32).

The mathematical formulation of either the dimensional analysis or the numerical solution of the kinetic equations proposed by Friedlander requires specific equations for the rate of coagulation and sedimentation. In addition, an appropriate kinetic equation must be chosen to describe the rate of change of the distribution. Friedlander (27) found that Smoluchowski's equation of coagulation by Brownian motion is an appropriate kinetic equation for atmospheric conditions. When this equation is used, a nonlinear partial integro-differential equation results for which an analytical solution is not possible. It is possible to reduce the partial integro-differential to a total differential by similarity transformations. This also reduces the number of independent variables. Two basic assumptions are made to perform this transformation: (1) that the size distribution function, $n(r) = dn/dr$, can be given by equation 2:

$$n(r) = g(t)\psi r/r_o(t) \qquad (2)$$

where $n(r)$, $g(t)$ and $r_o(t)$ are time-dependent and ψ is a dimensionless distribution function which is dependent only upon the dimensionless radius, $r/r_o(t)$; and (2) that a quasi-stationary equilibrium exists for the middle range of the size spectrum under investigation. Assumption (2) is necessary as the total particulate volume per volume of aerosol, ϕ, must be assumed constant and known for at least a short interval of time. ϕ is calculated from equation 3:

$$\phi = \int_0^\infty (4/3)\pi r^3 \, n(r) \, dr \qquad (3)$$

The total number of particles, N_t, per cm^3 in the atmosphere is given by equation 4:

$$N_t = \int_0^\infty n(r) \, dr \qquad (4)$$

By substituting equation 2 into equation 3 and 4, the time-dependent parameters, $g(t)$ and $r_o(t)$, can be evaluated as a function of N_t and two dimensionless equations. The equations are unique for any one size distribution and the resultant forms of $g(t)$ and $r_o(t)$ are given by equations 5 and 6, respectively:

$$g(t) = [N_t/r_o(t)] \, [\int_0^\infty \psi d(r/r_o(t)]^{-1} \qquad (5)$$

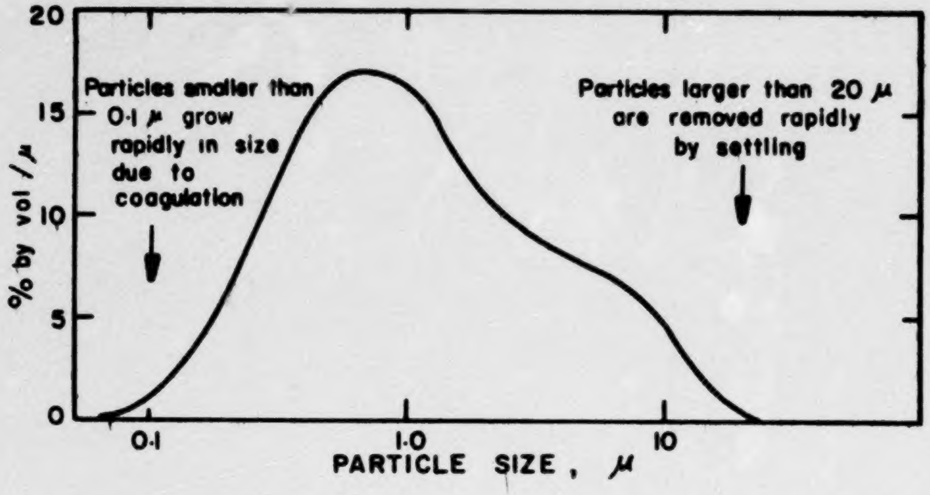


Figure 4. Coagulation and settling size limits as shown on a size-mass frequency plot of average airborne dust. (Whitby, 1965)

$$r_o(t) = 3\phi\int_o^\infty \psi d(r/r_o(t)) \;/\; 4\pi N_t\int_o^\infty (r/r_o(t))^3 \psi d(r/r_o(t)) \qquad (6)$$

Substituting the resultant forms of $g(t)$ and $r_o(t)$ into equation 2 results in equation 7 which is a self preserving form of the size distribution function,

$$n(r) = (N_t{}^{4/3} \;/\; \phi^{1/3})\; \psi_r\; [r(N_t/\phi)^{1/3}], \qquad (7)$$

where ψ_r is a dimensionless function different from ψ and dependent only on $r(N_t/\phi)^{1/3}$. Friedlander (25) has shown that when equation 7 is substituted into the equation describing the rate of change of the number-size distribution function with time for atmospheric aerosols, a total integro-differential equation for ψ_r results with $r(N_t/\phi)^{1/3}$ being equated to η_r as an independent parameter. Since η_r is independent of ψ_r the self preserving equation is a particular solution to the rate of change of the distribution function. The accuracy of the assumptions can be tested by plotting values of η_r versus ψ_r calculated from atmospheric size distribution measurements. The plot of data points should be a straight line on a log-log graph. An equation for the resultant line is expressable in terms of r, N_t and ϕ which, when substituted into equation 7, yields a size distribution function based only on ϕ and r.

Whitby and Clark (17) attempted to substantiate the self preserving theory by performing the above steps with their atmospheric data. The size distribution function which they formulated from their data is given as equation 8.

$$dN/dr = 0.05\phi r^{-4} \tag{8}$$

The measured number-size data of this study is evaluated in a similar manner.

In Friedlander's mathematical approach, the functional relationship between the particle size distribution function, n(r), and particle radius, r, is dependent upon the specific rate equation selected. Consequently, the results are not expected to be correct when variation in coagulation and sedimentation rates occur as a result or phenomenon not considered in the initial rate of change equations. Liu and Whitby (33) have shown that if the existence of a self preserving solution to the kinetic equation is assumed and the aerosol is in a state of dynamic equilibrium, then it follows that the size distribution function, n(r), is proportional to r^{-4}. In their analysis, the system or incremental volume is not necessarily closed and the mechanisms causing coagulation of particles is not restricted. It remains to be shown that atmospheric aerosols may be regarded as self preserving and in a state of dynamic equilibrium over a major portion of the size spectrum. The collection of time-dependent particle size and number data will contribute to the investigation of this theory.

C. Air Pollution and Meteorological Studies

Systematic research in air pollution meteorology was initiated over three decades ago when, in England, the dispersal of chemical warfare agents into the atmosphere was a military problem. Since that time, the analysis of air pollution has increasingly been undertaken in a systems context. Meteorological parameters and climatological conditions are a part of the system. Sources of aero-environmental contamination, atmospheric dispersal characteristics and pollutant receptor responses are of major concern to metropolitan settings and all are dependent on fluctuating atmospheric conditions. Pollutant sources and source strength are characteristically related to temperature, temperature and humidity ranges and wind speed and direction. Dispersion phenomena are thought to be highly dependent on wind speed, temperature and atmospheric stability. Meterological properties capable of causing receptor reaction to atmospheric pollution are difficult to evaluate but humidity, temperature and intensity of sunlight appear to predominate as factors capable of changing pollutant characteristics and initiating receptor response.

Gill _et_ _al_. (34) discuss meteorological instrumentation for use in air pollution surveys. Instruments which measure wind speed, direction and turbulence; temperature and temperature-difference; humidity; barometric pressure; solar radiation; precipitation; visibility and transmission of light are all appropriate candidates for use in experimental investigations. Hewson (35) reports on an array of instruments capable of measuring these parameters. Wind turbulence instruments, hygrometers, and actinometers generally require the closest surveillance for accurate data collection and interpretation. The care and operational performance of meteorological instruments has also been discussed by Hewson.

The proper setting, mounting and protection of instruments is necessary if representative measurements are to be obtained. Hewson (35) has reported on the location of instruments and errors which can result when improperly placed. The utilization of television towers for the installation of meteorological and sampling equipment has become quite common in recent years (36, 37, 38, 39). However, as reported by Hewson _et_ _al_. (40), the location of towers and instruments on them has not been standardized and they suggest reasonable vertical dimensions for spacing of sensors to obtain adequate meteorological information. Gill et al. (41) have reported on an analysis to predict the error associated with measurements taken from air streams which have previously passed through the tower structure. Munn and Stewart (38) have reviewed the use of meteorological towers in urban air pollution programs.

Atmospheric sampling and meteorologic monitoring programs have provided a better understanding of air pollution meteorology. The importance of atmospheric properties in the transport and dispersion of air pollutants is not readily apparent and various aspects of this phenomenon are currently being investigated. Hewson et al. (40) have discussed the research activities and results of wind turbulence and diffusion of particles in the lower atmosphere. Deland and Binkowski (39) used television towers to compare geostropic wind over Minneapolis, Minnesota and Louisville, Kentucky. Their findings were applicable to existing boundary layer models which estimate the wind speed and turbulent mixing over a city. DeMarrais (42) has investigated the vertical temperature profile over urban and rural areas and found that stability conditions are considerably less over open country.

The statistical variability in air pollution potential has been studied by Clarenburg (43). Karaper and Hopper (44) have reported on methods of measuring and forecasting the development of unfavorable pollution levels which result when atmospheric properties stabilize. In addition, Reifferscheid (45) has developed an inversion index system which characterizes inversion conditions on the basis of meteorological and orographic parameters as well as the actual measured aerosol concentration. With continued aerosol sampling and meteorological monitoring, the development of a forecast system based on particle number concentration may become more realistic.

Chapter III

COMPONENTS AND DEVELOPMENT OF PHYSICAL MEASUREMENT SYSTEMS

A. Particle Sizing and Counting System

The lack of adequate sizing and counting instrumentation for time-dependent studies of broad size spectrum aerosols prompted the development of the present automatic particle counting and sizing system.

The system is designed around three sizing and counting instruments, each of which is capable of counting and sizing particles of a specific size category. As combined, particles within the diameter size spectrum from 0.002 to 10 microns are sized and counted. A condensation nuclei counter, electrical particle counter and a light-scattering particle counter were selected as complementary instruments of the system for the following reasons:

1. No single instrument was available which could accurately size and count particles over the broad size spectrum characteristic of atmospheric aerosols.
2. Each instrument selected is accurate over a specific size range and the three ranges completely scan the entire spectrum from 0.001 to 10 microns.
3. In previous research at the University of Minnesota (9), these instruments were proven to be adequate for the intended application.

A Royco Model 220 optical particle counter, a General Electric Condensation Nuclei Counter and a University of Minnesota Electrical Particle Counter (EPC) were the specific particle sizing and counting instruments selected in the development of the complete system. Appropriate data acquisition equipment and several timer-actuated programmable switches were incorporated into the system to provide for complete automation of each instrument.

The instruments were chosen independently on the basis of operational characteristics and ability to meet the following criteria:

1. In situ count and size particles contained in discrete incremental size categories within the size spectrum from 0.001 to 10 microns in diameter.
2. Provide accurate counts at concentration levels as high as 10^7 particles per cubic centimeter (with dilution).
3. Maintain a sampling flow rate of no less than 0.1 cfm per measurement method.
4. Be adaptable to automation techniques and respond to an automatic scanning of the size spectrum at least every 10 minutes.

1. Optical Particle Counter

The Royco Model 220 optical particle counter is manufactured and distributed by Royco Instruments, Inc., Menlo Park, California. The instrument is highly automated and capably of simultaneously counting particles within four distinct size categories. The photo-multiplier tube receives light scattered from the particle at an angle 90° removed from the light source beam. The pulse height analyzer is preset to group pulse heights into four categories representing equivalent particle diameters within the ranges from 0.5 to 1.0, 1.0 to 2.0, 2.0 to 4.0 and greater than 4.0 microns. The particle number count accumulated in each range during a one-minute sampling period is displayed by "nixie" indicators and recorded on paper tape through a digital recorder.

The Royco Model 220 particle counter is designed to sample at a rate of 0.1 cfm. "Coincidence loss" at this flow rate does not exceed 10 percent when the total measurable particle concentration level is less than 3×10^6 particles per cubic foot.

Basically, light scattered from a particle is detected by a photomultiplier tube which responds by producing an electronic pulse. Each pulse is assumed to be due to a single particle and the pulse height is considered to be proportional to the square of the particle diameter. Consequently, a summation of pulses within specific pulse height ranges during a selected time period yields the number of particles within a predetermined size range per volume of sample air.

Unfortunately, the pulse height is not only a function of the equivalent particle diameter but also of the particle's optical characteristics, and this latter contribution can be sufficient to produce erratic and erroneous results. Another source of error results when two or more particles, capable of scattering an appropriate amount of light, pass through the viewing field at the same time. This phenomenon results in a single, higher pulse which is interpreted by the electronic circuitry as one larger particle. Errors of this nature are called "coincidence loss" and are generally controlled by designing a small viewing field with a commensurate sampling flow rate and, when necessary, by adding "clean" dilution air to the sample gas stream. A diagram of the "clean" air dilution system used in this study is shown in Figure 5.

2. Condensation Nuclei Counters

Condensation nuclei counters, like optical particle counters, use optical techniques to determine the sampled air particle concentration. However, nuclei are less than 0.1 micron in diameter and are not effective in scattering light. To overcome this condition, the nuclei counter is designed to produce a water droplet from each nucleus present in the sample and measure the quantity of light transmitted through the droplet medium. The number of nuclei present is determined by relating light transmission through the sample before and after droplet formation.

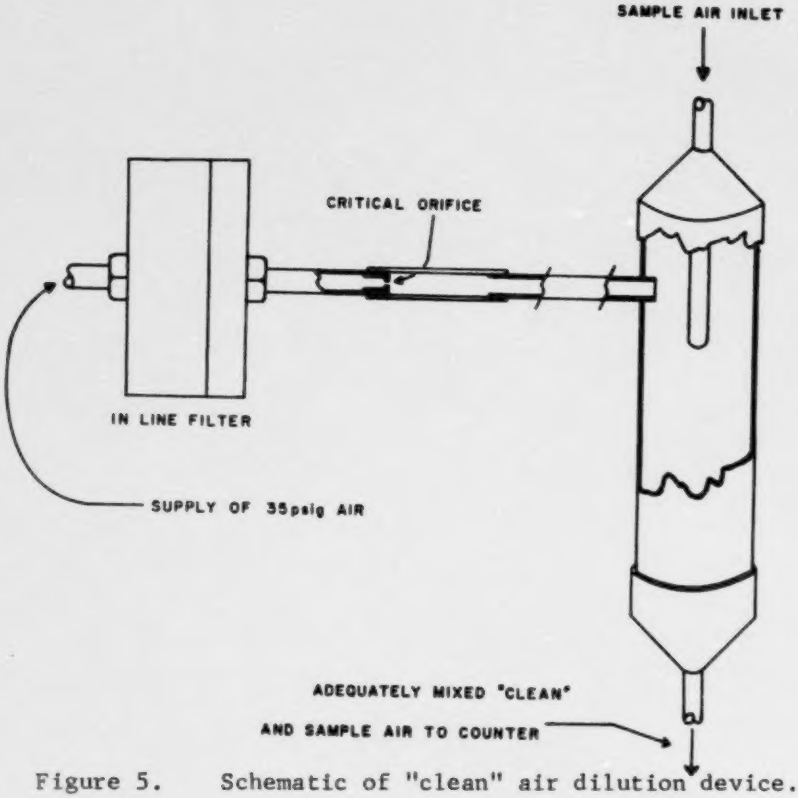

SAMPLE AIR INLET
CRITICAL ORIFICE
IN LINE FILTER
SUPPLY OF 35psig AIR
ADEQUATELY MIXED "CLEAN"
AND SAMPLE AIR TO COUNTER

Figure 5. Schematic of "clean" air dilution device.

The General Electric nuclei counter continually forms and grows water droplets in the following manner. Sample air is brought to saturation by passing it through a humidifier while being directed toward an expansion chamber. The entrance and exit ports of the expansion chamber contain motor-driven rotary valves which open and close in a systematic manner. Downstream from the expansion chamber a regulated source of vacuum pulls the sample air through the system. The rotary valves open and close in a cyclic manner while allowing for the expansion of air and droplet formation in the expansion chamber. A rotary valve cycle begins with both valves open and air flowing through the system. The second step in the cycle initiates the closing of both valves and the vacuum source continues to operate, pulling a vacuum on the system downstream of the expansion chamber. The exit valve opens and the air in the expansion chamber is suddenly exposed to an under-pressure equivalent to the regulated vacuum source. The droplets form at this stage of the cycle. The cycle is completed with the opening of the inlet valve to the expansion chamber and, with both valves open, the droplet-laden air is flushed from the chamber as a new sample flows through the system. During the under-pressure portion of the cycle, the sample air in the expansion chamber is suddenly expanded, adiabatically cooled and super-saturated. Under these conditions water vapor condenses on the nuclei and the water droplets rapidly grow to a size capable of scattering light. The amount of light transmitted through the droplet media is proportional to the number of droplets present in the chamber and to their scattering or adsorbing area. A measure of the quantity of light reaching a photomultiplier tube located in the expansion chamber is related to the number of nuclei originally present in the sample air.

Exposed to a super-saturated atmosphere at a vacuum of 8 inches of mercury, a 0.001 micron particle acts as a nucleus for droplet formation and a 5 micron water drop is obtained in about 26 msec. During this near-instantaneous rate, all nuclei, regardless of initial size, grow to virtually the same droplet diameter (5 microns). Consequently, the output signal from the phototube becomes only a function of the number of nuclei originally present in the sample air.

The General Electric condensation nuclei counter is designed to operate at a set vacuum in the expansion chamber. Operated at a vacuum of 8 inches of mercury, the sample rate is 100 cc per sec and nuclei present in the sample ranging in size from 0.1 to 0.001 micron are counted. Six linear ranges capable of indicating full scale nuclei concentrations of 300, 1000, 3000, 10 K, and 100 K per cubic centimeter are provided. In addition, two nonlinear ranges with full-scale deflection readings of 1 M and 10 M nuclei per cubic centimeter are available to measure extremely high concentrations. The response time is 2 seconds and particle count readings above 0.3 full-scale are reported by the manufacturer to be ± 25% accurate (10). A complete rotary valve cycle is completed five times a second. The response of the photomultiplier tube and associated electronic circuitry is sufficient to provide an essentially continuous measure of nuclei present in the sample.

3. Electrical Particle Counter (EPC)

The EPC was developed at the University of Minnesota by Whitby and Peterson while investigating methods to count and classify particles ranging from 0.01 to 1 micron in diameter (9). The instrument is the result of incorporating several unique components into a compatible system. The components are: (1) a charger which is stable and capable of imposing distinctly different charges on different sized particles; (2) an electrical mobility analyzer which maintains a uniform electric field, collects particles in discrete mobility ranges at values as low as 0.0002 cm/sec per volt/cm, and maintains laminar flow characteristics at large air flow rates and (3) a sensing circuit capable of measuring and amplifying electrical signals in the range of 10^{-14} to 10^{-12} ampere.

A schematic diagram of the EPC is shown in Figure 6. Operational design characteristics are as follows: Sample air enters a special diffusion charger through an annular slit where the aerosol is mixed with a stable negative ion supply generated by a sonic jet ionizer. A short distance from the ionizer the ion concentration is nearly independent of the initial concentration and within the aerosol-ion mixing region the ion concentration is considered to be constant. This phenomenon is shown to be true with the aid of equation 9 which identifies

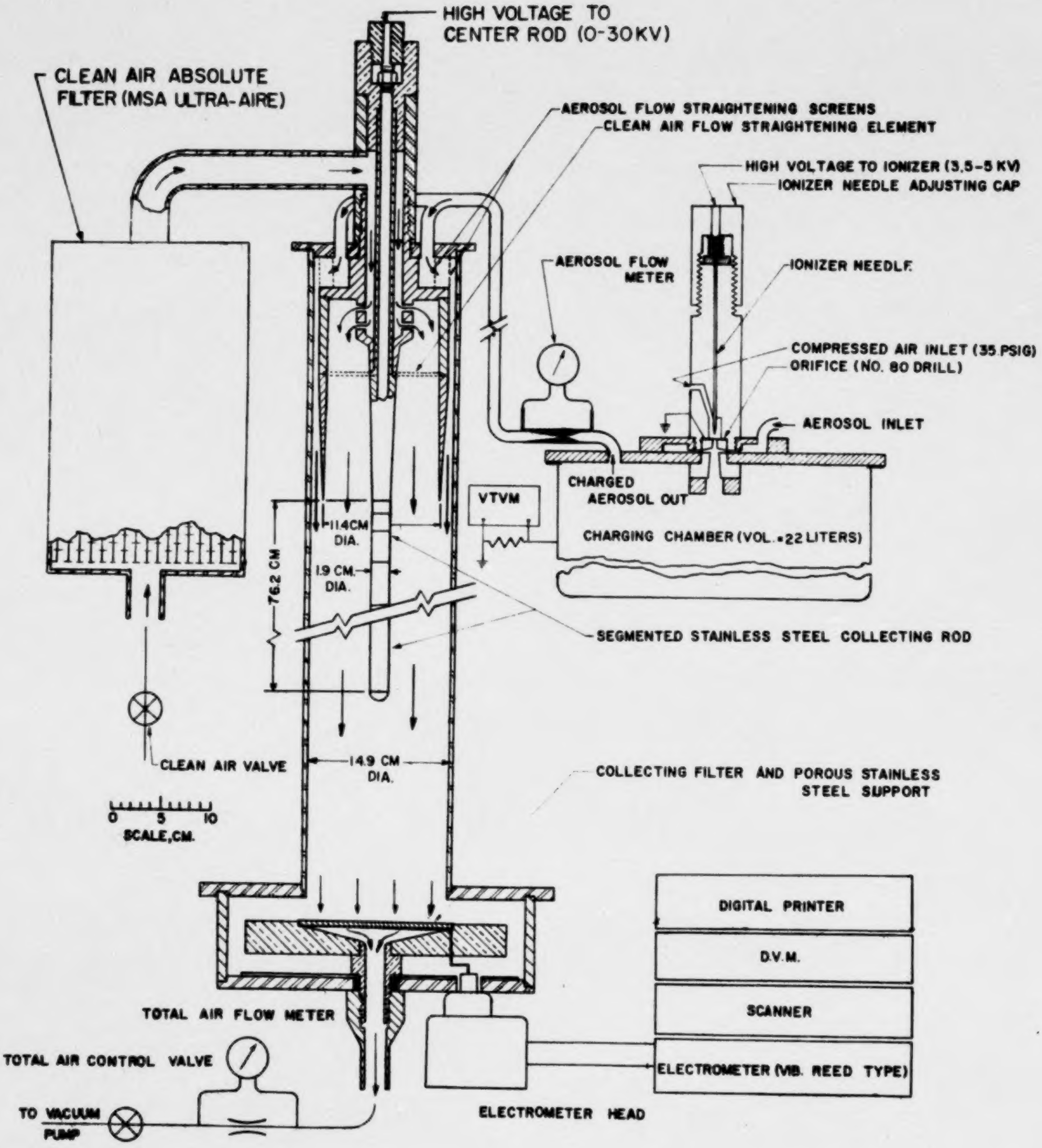

HIGH VOLTAGE TO CENTER ROD (0-30KV)
CLEAN AIR ABSOLUTE FILTER (MSA ULTRA-AIRE)
AEROSOL FLOW STRAIGHTENING SCREENS
CLEAN AIR FLOW STRAIGHTENING ELEMENT
HIGH VOLTAGE TO IONIZER (3.5-5 KV)
IONIZER NEEDLE ADJUSTING CAP
AEROSOL FLOW METER
IONIZER NEEDLE
COMPRESSED AIR INLET (35 PSIG)
ORIFICE (NO. 80 DRILL)
AEROSOL INLET
CHARGED AEROSOL OUT
VTVM
CHARGING CHAMBER (VOL.=22 LITERS)
11.4CM DIA.
1.9 CM. DIA.
76.2 CM
SEGMENTED STAINLESS STEEL COLLECTING ROD
CLEAN AIR VALVE
14.9 CM DIA.
COLLECTING FILTER AND POROUS STAINLESS STEEL SUPPORT
0 5 10
SCALE,CM.
DIGITAL PRINTER
D.V.M.
SCANNER
ELECTROMETER (VIB. REED TYPE)
TOTAL AIR FLOW METER
TOTAL AIR CONTROL VALVE
TO VACUUM PUMP
ELECTROMETER HEAD

Figure 6. Schematic of the electrical particle counter.

ion decay within a unipolar ion cloud.

$$N = N_o / (4\pi e \, Z_i \, N_o \, t + 1) \qquad (9)$$

Where: N = ion density at a particular time, number/cm^3

N_o = initial ion density produced, number/cm^3

$e = 4.8 \times 10^{-10}$ stat coul.

Z_i = ion mobility, cm/sec per stat volt/cm

t = time, seconds.

For small ions, the quantity $4\pi e Z_i$ is about equal to 3.6×10^{-6}, and when $N_o t$ is greater than 10^6 the ion density is nearly independent of the initial concentration. In the special diffusion charger, $N_o t$ is greater than 10^6 when the ions are mixed with the aerosol.

The charge acquired by a particle of diameter (D_p) within the ion-aerosol mixing region is dependent on the ion concentration, N, and the exposure time, t. Several charging chamber designs were tried and the configuration which produced the optimum particle charge characteristics is shown in Figure 7. The complex geometry of the charging section does not lend itself to an exact determination of the Nt product. However, Whitby and Clark (17) established an Nt value of 1.8×10^7 and, through experimental studies, collected data which are nearly equal to the theoretical charge data calculated on the basis of Nt equal to 10^7. The theoretical curve was determined by applying the Nt value to the Bricard equation which relates Nt, particle diameter and rate of aerosol charging for any mean free path to the conditions when an electric field exists.

Experimental investigations have shown that the Nt values obtained are sufficient to charge a high percentage of the particles larger than approximately 0.05 micron and a fraction of the smaller particles. An instrument efficiency factor is applied in the calculations to account for the fraction of electrically neutral particles and for space charge loss of particles while contained in the aerosol charging chamber. The efficiency factor was theoretically determined and

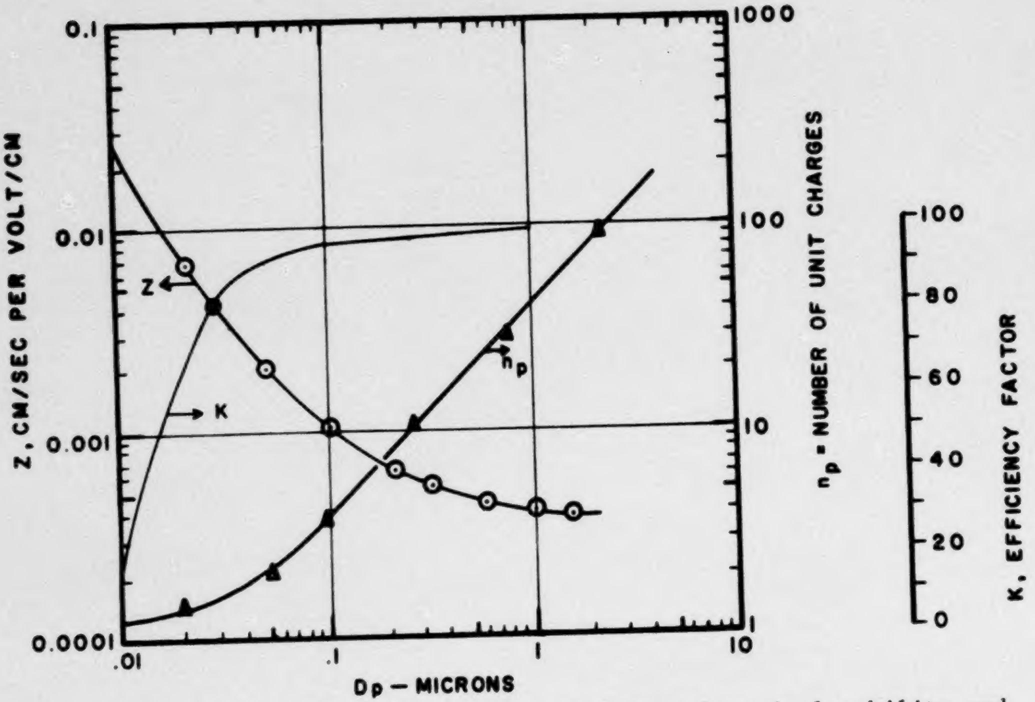


Figure 7. Particle charge, resultant electrical mobility and efficiency factors for the EPC.

experimentally verified for various-sized particles and the resultant efficiency curve is given in Figure 7. This Figure also contains the experimentally-determined charge and electrical mobility characteristics of the aerosolized particles after passing through the diffusion charger.

When thoroughly mixed with negative ions, the respective sized particles possess a unique negative charge and flow with the sample air through a calibrated flow restriction to the mobility analyzer. The sample air enters the upper section of the mobility analyzer in a thin annular stream bounded externally by a cylindrical metal tube and internally by clean air flowing directly through the analyzer. Laminar flow is maintained and the sample and clean air pass through the analyzer with true identity. When a positive voltage gradient is applied between the grounded external cylinder and the concentrically-mounted metal rod (collecting rod), an electrical field is created which causes the negatively-charged particles to move from the sample air stream into the clean airflow. If either the particle mobility or the voltage gradient is of sufficient magnitude, a portion of the charged particles penetrates the core of clean air and they are then collected on the metal rod. The charged particles not collected are filtered downstream from the analyzer section. The charge induced on the filter media by the filtration of charged particles is measured with a vibrating-reed electrometer and recorded as a filter current. The filter current reading is a function of the particle charge and number of particles filtered. These readings vary from a background of 10^{-14} ampere to approximately 10^{-11} ampere when filtering highly concentrated aerosols. In operation, the positive voltage is varied in discrete steps and, corresponding to each voltage setting, a different filter current is read. The difference between adjacent filter current readings is applied in equation 10 to determine the particle number concentration within a respective size interval.

$$N_c = \Delta I / (e\ n_p\ Q_a\ K) \qquad (10)$$

Where N_c = number concentration in a particular size range as influenced by the voltage gradient, particle charge and airflow rate.

ΔI = difference in two filter current readings corresponding to the upper and lower limits of the voltage gradient applied.

e = elemental ion charge, 4.8×10^{-10} stat coul.

n_p = number of unit ion charges per particle.

Q_a = mobility analyzer aerosol flow rate, cm^3/sec.

K = instrument efficiency factor.

Optimum operating conditions of the EPC constructed for this system are: clean airflow rate of 2.63 cfm, a sample procurement rate of 0.765 cfm and an ionizer flow of 0.2 cfm. During automatic operation, the size range from 0.015 to approximately 1.0 micron particle diameter size was scanned and the number of particles within nine sub-range sizes was determined. The sub-range sizes were as follows: 0.015 - 0.02; 0.02 - 0.03; 0.03 - 0.04; 0.04 - 0.06; 0.06 - 0.08; 0.08 - 0.1; 0.1 - 0.2; 0.2 - 0.3; 0.3 - 0.5. Table I lists the applied collection voltage needed to collect all particles smaller than the stated particle size when the airflow through the EPC was maintained at the previously noted rates. Other voltages may be applied but, in this study, only the voltage values listed in Table I were used.

Table I. Particle Collection Voltage Necessary to Remove All Particles Smaller Than Stated Size.

Particle Diameter Size --microns--	Voltage Applied --volts--
0.015	550
0.02	860
0.03	1440
0.04	2118
0.06	3350
0.08	4570
0.1	5705
0.2	8930
0.3	10686
0.5	12415

4. Combining and Automating the Three Basic Particle Counters

A block diagram showing the basic components of each of the three basic particle counting instruments assembled to complement the broad spectrum particle counting system is presented in Figure 8. The General Electric Condensation Nuclei Counter and the Royco Particle Counter were incorporated into the system as basic units with essentially no major modification. The EPC was automated before being combined with the other two units.

Automation of the EPC was accomplished by providing a means of stepping and recording the voltage applied to the center collecting rod, measuring the filter current at each setting and monitoring the ion current generated by the special diffusion charger. The voltage gradient between the collecting rod and the outer cylindrical casing was established by one of two voltage power supplies. The use of two power supplies was necessary since no single variable power supply was sufficiently stable over the range from 0-20 kv.; therefore, a low (0-3000 v.) and a high (0-20,000 v.) voltage power source were combined to independently supply the required voltage to the collecting rod. Each power supply was modified to permit automatic voltage selection and control of the operational period. Automatic voltage selection was accomplished by substituting ten variable power-stat transformers in place of the commercially-supplied transformer in each power supply.

A ten-switch timer was placed between the step-up voltage transformers and the ten powerstat transformers. Only one switch of the timer was closed during a particular time and, during this period, the voltage setting was applied to the step-up transformers; thus, a proportional output voltage was maintained. The timer sequentially switches a single preset powerstat transformer into the proper voltage power supply circuitry once during a single measurement cycle so that ten different collecting voltages are applied to the collecting rod during a cycle. As thus automated, the voltage is changed once every minute and the complete voltage spectrum is scanned every ten minutes.

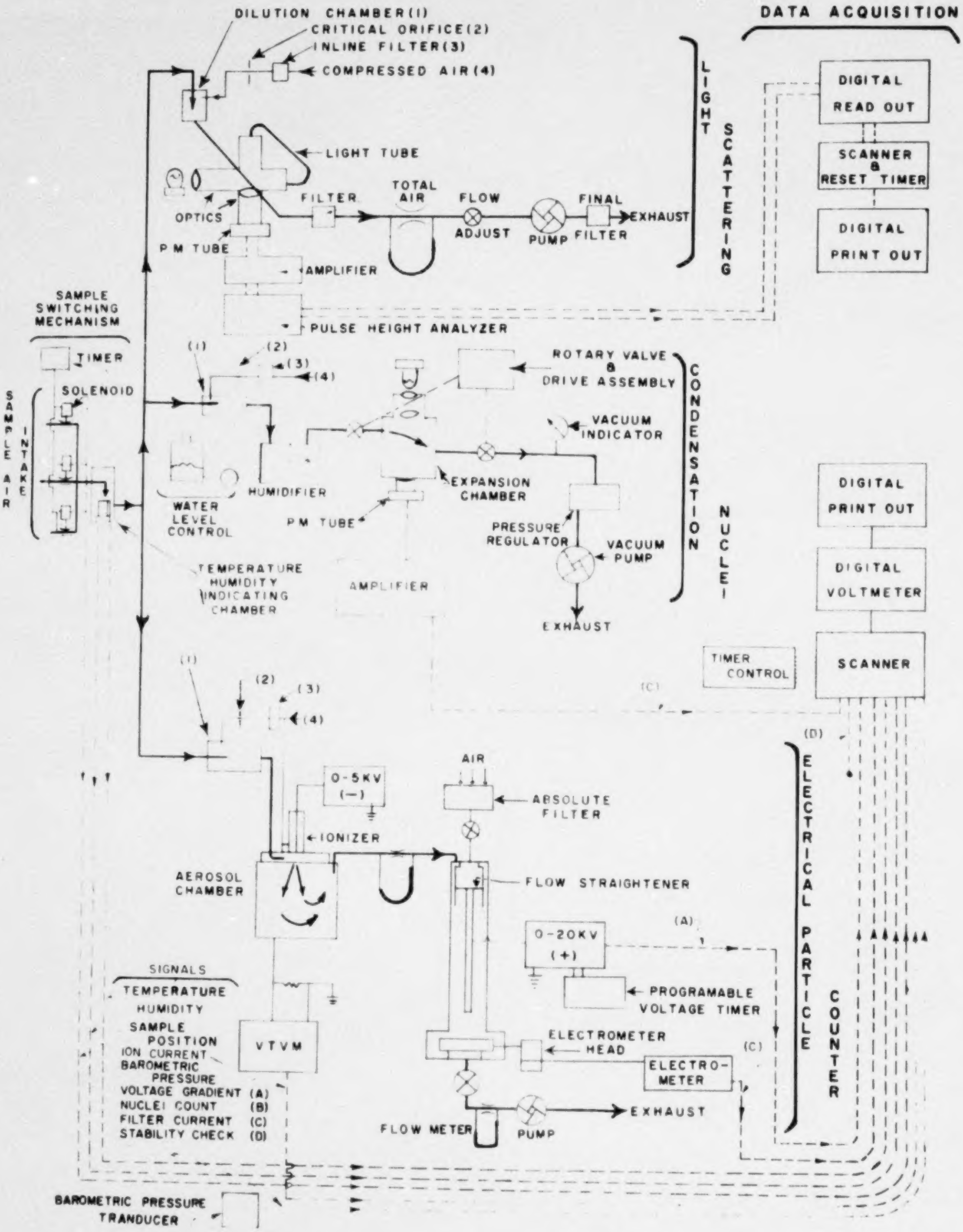

DILUTION CHAMBER(1)
CRITICAL ORIFICE(2)
INLINE FILTER(3)
COMPRESSED AIR(4)
LIGHT TUBE
OPTICS
P M TUBE
FILTER
TOTAL AIR
FLOW ADJUST
PUMP
FINAL FILTER
EXHAUST
AMPLIFIER
PULSE HEIGHT ANALYZER
LIGHT SCATTERING
DATA ACQUISITION
DIGITAL READ OUT
SCANNER & RESET TIMER
DIGITAL PRINT OUT
SAMPLE SWITCHING MECHANISM
TIMER
SOLENOID
SAMPLE AIR INTAKE
(1)
(2)
(3)
(4)
ROTARY VALVE & DRIVE ASSEMBLY
VACUUM INDICATOR
HUMIDIFIER
EXPANSION CHAMBER
WATER LEVEL CONTROL
PM TUBE
PRESSURE REGULATOR
VACUUM PUMP
TEMPERATURE HUMIDITY INDICATING CHAMBER
AMPLIFIER
EXHAUST
CONDENSATION NUCLEI
DIGITAL PRINT OUT
DIGITAL VOLTMETER
TIMER CONTROL
SCANNER
(C)
(D)
AIR
0-5KV (−)
ABSOLUTE FILTER
IONIZER
AEROSOL CHAMBER
FLOW STRAIGHTENER
(A)
0-20KV (+)
PROGRAMABLE VOLTAGE TIMER
ELECTROMETER HEAD
ELECTRO-METER
(C)
VTVM
EXHAUST
FLOW METER
PUMP
ELECTRICAL PARTICLE COUNTER
SIGNALS
TEMPERATURE
HUMIDITY
SAMPLE POSITION
ION CURRENT
BAROMETRIC PRESSURE
VOLTAGE GRADIENT (A)
NUCLEI COUNT (B)
FILTER CURRENT (C)
STABILITY CHECK (D)
BAROMETRIC PRESSURE TRANDUCER

Figure 8. Schematic of the broad spectrum particle counting and sizing system.

The filter current is measured by a vibrating-reed electrometer and the data are recorded in terms of equivalent millivolt values on digital tape. With the electrometer properly zeroed and preset on a specific detecting range, it is sufficiently sensitive to detect and transmit filter current variations as a function of the atmospheric particle number concentration. Signals slightly greater than the specific preset range were accurately measured and recorded. Collecting rod voltage changes produce negligible transient effects on the electrometer and the readings are basically stable 30 seconds after a voltage change has occurred. A linear operational amplifier having rapid response characteristics and generally less drift associated with the output signal would be an acceptable filter current detector. In this study, the results from a linear amplifier were acceptable but the output signal was not compatible with the millivolt signals generated by other components of the system.

When a sufficient number of ions are being generated by the sonic jet ion generator to properly charge the particles there is deposition of excess ions onto the walls of the charging chamber. Once the ions are deposited, there is a current flow to ground and this current is continuously monitored with a Triplet VTVM and intermittently recorded to assure the investigator that a sufficient number of ions are being generated. A low or fluctuating ion current measurement is indicative of a low ion concentration which destroys the charge-to-particle diameter relationship and during these periods the filter current reading can not be related to the particle number concentration. In general, the ion current is very stable and the amount of data lost because of improper ion generation is minimal.

Data acquisition and subsequent printing of data on paper tape was accomplished by using two separate systems. One system was used for the optical particle counter and the other system accepted and recorded signals from all other monitoring instruments. The optical particle counter was equipped with a digital readout, a scanner and a printout assembly. The data recorded in this instance were the number of particles counted in each of the four size ranges previously noted. The count data are cumulative for a one-minute sampling period. All other signal values recorded are instantaneous measurements for a specific point in time.

The second data system is composed of a Dana Model No. 730 Scanner and Model No. 5400 Digital Voltmeter complemented by a Hewlett-Packard Model No. 562A Digital Printer. The scanner, equipped with individual snap-in guarded relay switches, is capable of accommodating thirty independent signals. The digital voltmeter measures the respective signals on a 0 - 100 mV range and the data are printed on paper tape. The millivolt scanner is controlled by an array of switches which are timer-activated. The scanner was modified by the addition of the timer switches to permit the sensing and recording of specific signals more than once during each complete cycle. Ten minutes are required to span the complete particle size spectrum. Each minute of operation results in a complete set of printed data which, when analyzed, results in the number of particles detected within a specific size range. The array of printed data for a one-minute sampling period is shown in Figure 9. The recorded data are inclusive of the following information: particles counted in the detection range of the optical particle counter, EPC collection voltage, EPC ion current, EPC filter current, relative humidity of the sample air, sample air inlet temperature, sample procurement location, nuclei concentration and voltmeter zero check. The EPC ion current and voltmeter check are recorded to indicate the proper performance of the system while operating in the automatic mode. These values do not enter into any of the calculations. All data not applicable to a specific aerosol investigation may be deleted by removing the appropriate signal from the scanner relay switch. Additional signals, up to a total of thirty, may be recorded by providing

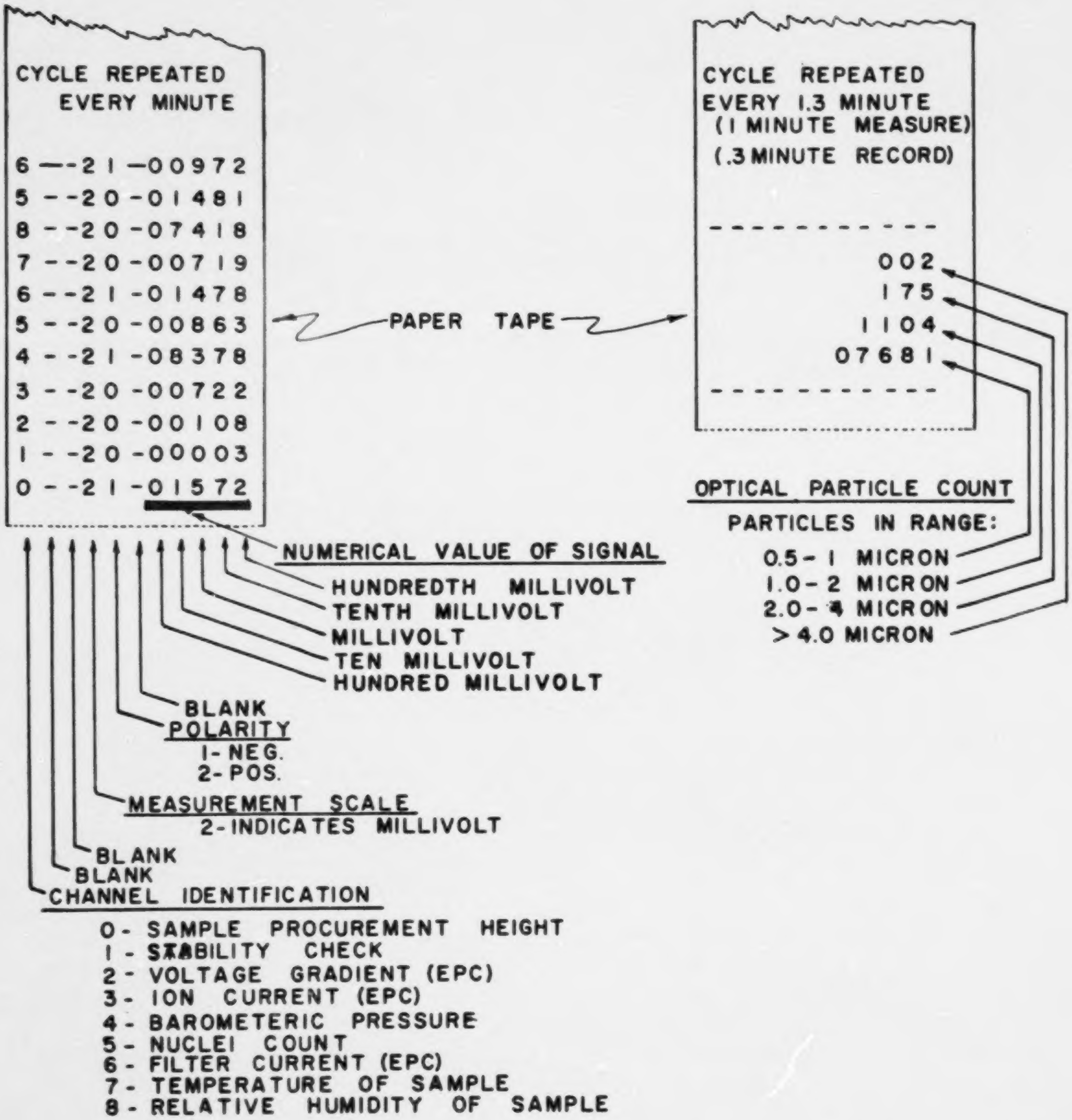

CYCLE REPEATED EVERY MINUTE
6 --21-00972
5 --20-01481
8 --20-07418
7 --20-00719
6 --21-01478
5 --20-00863
4 --21-08378
3 --20-00722
2 --20-00108
1 --20-00003
0 --21-01572
PAPER TAPE
CYCLE REPEATED EVERY 1.3 MINUTE
(1 MINUTE MEASURE)
(.3 MINUTE RECORD)
002
175
1104
07681
NUMERICAL VALUE OF SIGNAL
HUNDREDTH MILLIVOLT
TENTH MILLIVOLT
MILLIVOLT
TEN MILLIVOLT
HUNDRED MILLIVOLT
BLANK
POLARITY
1- NEG.
2- POS.
MEASUREMENT SCALE
2-INDICATES MILLIVOLT
BLANK
BLANK
CHANNEL IDENTIFICATION
0- SAMPLE PROCUREMENT HEIGHT
1 - STABILITY CHECK
2 - VOLTAGE GRADIENT (EPC)
3 - ION CURRENT (EPC)
4 - BAROMETERIC PRESSURE
5 - NUCLEI COUNT
6 - FILTER CURRENT (EPC)
7 - TEMPERATURE OF SAMPLE
8 - RELATIVE HUMIDITY OF SAMPLE
OPTICAL PARTICLE COUNT
PARTICLES IN RANGE:
0.5 - 1 MICRON
1.0 - 2 MICRON
2.0 - 4 MICRON
> 4.0 MICRON

Figure 9. Display of data as recorded by the data acquisition equipment used with the particle system.

a millivolt signal to the scanner from an appropriate sensing device. Data reduction of the printed millivolt signal values begins with the conversion of each value to the actual magnitude of the parameter being measured. Further analysis of data is dependent upon the function each parameter plays in the investigation of a specific aerosol.

With the cooperation of Dr. Whitby, the facilities of the Particle Technology Laboratory (University of Minnesota) were used to evaluate the particle counters on the basis of counting and sizing homogeneous test aerosols. Prior to this evaluation, Whitby and Vomela (7) had evaluated the response of single particle light scattering counters to "nonideal" particles. Whitby *et al*. (9) and Whitby and Clark (17) had reported on the effective sizing and counting of particles with the electrical particle counter and Rich (11) had discussed the accuracy and application of the condensation nuclei counter.

Two of the three optical particle counters evaluated by Whitby and Vomela were operated in conjunction with the Royco Model No. 220 optical particle counter used in this study to establish a comparative overall counting and sizing calibration of the latter counter. The counters were the Royco Model 200 and the Bausch & Lomb Model 40-1. For test purposes, a homogeneous aerosol was generated from polyvinyltoluene and polystyrene latex spheres available from Dow Chemical Company. The spheres were 0.556, 0.796, 1.9 and 2.68 microns in diameter. The two larger sized particles were dispersed with a Collision Atomizer and the smaller ones were made airborne with the same apparatus but an impactor was added to the system to remove large droplets and improve the homogeneity of the aerosol. Each particle counter was positioned and operated to simultaneously sample air from a single aerosol cloud. The possibility of a particular counter sampling a unique particle concentration within the cloud was dismissed on the basis of results obtained by interchanging counters while duplicating individual tests.

Each counter recorded approximately the same count at each location. The average results obtained while conducting the comparative sizing and counting test with the three optical counters are given in Tables II and III.

Table II: Comparative Counting Calibration Results of Three Optical Particle Counters

Particle Counter	Test Aerosol Particle Size, Microns			
	0.556	0.796	1.90	2.68
	Particle Counts per Cubic Foot of Sample Air			
Royco No. 220	1.55×10^4	4.24×10^4	3.09×10^4	1.25×10^4
Bausch & Lomb No. 40-1	1.70×10^5	6.80×10^4	6.43×10^4	3.18×10^4
Royco No. 200	8.08×10^4	3.38×10^4	2.17×10^4	1.29×10^4

Several comments regarding the results shown in Tables II and III may be made. When counting 0.556 micron particles there is considerable variation in the number of particles detected by the three counters. Approximately ten times more particles were counted by the Bausch & Lomb counter and five times more with the Royco No. 200 than with the Royco No. 220. For all other test particle sizes, the counting results from each instrument were experimentally comparable. The 0.556 micron particle counting difference is explained on the basis of the lower particle size detection limit of each instrument. The Bausch & Lomb and the Royco No. 200 have a 0.3 micron detection limit whereas the Royco No. 220 has a 0.5 micron limit. It therefore appears that a percentage of the generated aerosol was being detected in the smaller size ranges by the Bausch & Lomb and Royco No. 200 counters and, due to the larger detection limit of the Royco No. 220, these particles were not detected by the latter. Except for the classification of the

Particle Counter	Counter Sizing Characteristics		Test Aerosol Particle Size, Micron (Diameter)							
			0.556		0.796		1.9		2.68	
	Endpoint of particle range, μ	Midpoint of particle range, μ	Particle count in range	% less than size	Particle count in range	% less than size	Particle count in range	% less than size	Particle count in range	% less than size
Royco 220	0.5			0		0		0		0
		0.75	1519[a]		4141.5[b]		376.6[c]		296.6[b]	
	1.0			97		97.6		12.2		23.6
		1.5	37		99.3		2454.7		196.2	
	2.0			99.9+		99.9+		91.6		39.3
		3.0	0		0.5		260.8		761.4	
	4.0							99.9+		99.9+
		6.0	0		0		0		0	
	8.0									
Bausch and Lomb 40-1	0.3			0		0		0		0
		0.4	1447[c]		237[c]		216[c]		418[c]	
	0.5			58.9		36.9		36.1		68.9
		0.75	973		388.5		29		48	
	1.0			98.6		97.4		41.0		76.8
		1.4	35		16.5		0		13	
	1.8			99.9+		99.9+		41.0		78.9
		1.9	0		0		241		0	
	2.0							81.3		78.9
		2.5					112		123	
	3.0							99.9+		99.2
		4.0					0		5	
	5.0									99.9+
Royco 200	0.3									
		0.35	107[d]		6.5[d]		18[d]		31[d]	
	0.4			12.6		3.2		12.0		24.8
		0.45	289		7		11		23	
	0.5			46.8		6.7		19.3		43.2
		0.55	421		15		6		14	
	0.6			96.5		14.1		23.3		54.4
		0.7	20		60		14		4	
	0.8			98.8		43.8		32.7		57.6
		0.9	7		111.5		3		5	
	1.0			99.6		99.0		34.7		61.6
		1.1	2		1		6		2	
	1.2			99.9		99.5		38.7		63.2
		1.35	1		1		14		3	
	1.5			99.9+		99.9+		48.0		64.8
		1.75	0		0		31		3	
	2.0							68.7		67.2
		2.5					46		4	
	3.0							99.3		70.4
		3.5					1		35	
	4.0							99.9		98.4
		4.5					0		2	
	5.0							99.9+		99.9

a- average of six counts
b- average of four counts
c- average of two counts
d- average of three counts

Table III. Comparative sizing calibration of three optical particle counters.

2.68 micron particles, all specifically sized particles were primarily enumerated in the proper size range channel. In the 2.68 micron particle tests all counters recorded a large number of particle counts in the lower particle size channels. Consequently, a large number of small heterogeneous-sized particles must have been present in the 2.68 micron aerosol cloud.

After the EPC was assembled and the flow meters calibrated the instrument was evaluated for laminar flow pattern characteristics, ion production and particle sizing and counting accuracy. Accurate particle sizing and counting with the EPC is dependent on the presence of laminar air flow through the mobility analyzer. The air flow pattern is defined by generating a uranine dye aerosol composed of particles with a mean mass particle size of 0.2 micron and sampling from the aerosol cloud. With laminar flow and no voltage applied to the collecting rod of the EPC, the sample air will flow through the unit and be collected on the afterfilter in a ring concentric to the circular clean air filtering area. Under ideal conditions, the width of the ring would be 1.75 cm which is equal to the width of the sample air inlet. With turbulent flow the particle deposition occurs across the total filter area. The concentration of particles flowing through the EPC is sufficiently high to provide a visible collection pattern on the afterfilter after ten minutes of operation. A fluorometric analysis of the uranine particles collected on the inner portion of the filter and the outer concentric ring was performed. From this analysis, it was established that less than six percent of the particles penetrated the boundary of sample and clean air and were collected on the clean air filter area.

A dry test meter, which had been standardized by the Minnegasco meter test department, was used to calibrate the total air flow and aerosol sample flow orifice. The gas meter was also used to establish the air flow through the sonic jet ionizer.

Ion production from the sonic jet ionizer was verified by measuring the current flow from the isolated ion chamber to ground with a Keithley 620-B electrometer. This current is continually monitored with a less-sensitive Triplett VTVM.

The ability of the EPC to accurately discriminate between various sized particles and subsequently generate a measureable signal was tested by two methods. The first method was a comparative test between this unit and an equivalent model belonging to the Particle Technology Laboratory. The latter instrument had been thoroughly evaluated as to particle collection, sizing, enumeration and deposition and the results reported by Whitby _et al_. (9).

The second method of evaluation was conducted by generating a known particle number-size distribution and sampling the aerosol with the EPC. The aerosol was generated with the atomizer-impactor arrangement from a 1% uranine solution. The particle distribution generated had previously been determined by electron microscopy procedures. The signals generated by the EPC when sampling the known aerosol were evaluated to provide a resultant particle number-size distribution. The known distribution and that calculated from the EPC data are shown in Figure 10. Experimentally, the distributions are considered to be comparable.

As discussed by Rich (11), the absolute calibration of nuclei counters is difficult. The performance of the nuclei counter purchased for this study was compared to one belonging to the Particle Technology Laboratory. Initial sampling results were not comparable but upon establishing the proper voltage setting at each critical check point, the counts recorded by each instrument were similar for all nuclei counting ranges except the 300 to 1000 nuclei per cubic centimeter ranges. A nuclei concentration lower than 10,000 per cubic centimeter is not expected to occur during normal atmospheric conditions and the reason for the

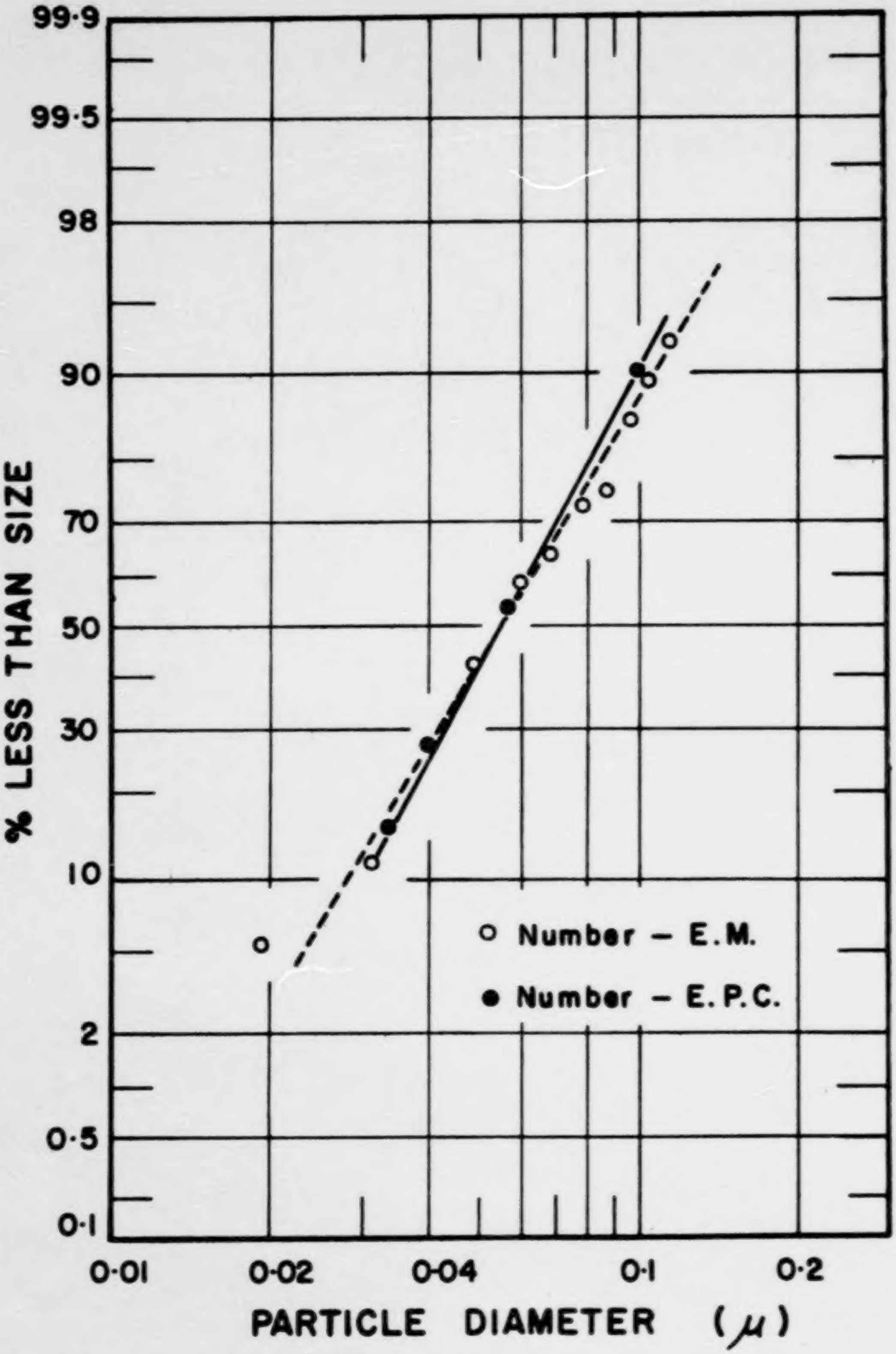


Figure 10. Cumulative number-size distribution of 1% uranine dye aerosol sized by electron microscopy and the EPC.

inconsistency in counts within these two ranges was not determined during the comparative tests. Subsequent to the collection of all data in this study, the nuclei counter was returned to the factory for repair and a calibration check. General Electric Laboratories reported the instrument to be within the calibration range of their standardizing techniques.

B. Meteorological Instrumentation Used in Study

An array of meteorological instruments were operated concurrently with the operation of the particle counting and sizing instruments. The parameters measured were: temperature, wind speed and direction, relative humidity, barometric pressure, direct radiation and precipitation.

Temperature sensing and recording instrumentation consisted of three aspirated thermohm temperature sensors and a Leeds and Northrup Speedomax G recorder. The sensors are located on a television tower at 70, 170 and 500 feet above ground level. The signal from the 70-foot sensor is recorded as ambient temperature in terms of Fahrenheit degrees. The 170- and 500-foot sensor signals are conditioned by the 70-foot signal and the value recorded is degree temperature difference between the 70-foot level and the respective height. Temperature variation with height is readily noted by this type of recording. A positive temperature difference denotes a temperature inversion.

Aerovane wind systems were used to monitor wind speed and direction. This is the same type system which has been adopted by the U.S. Weather Bureau, Federal Aeronautical Agency and the military services to obtain wind information. Three separate systems are used at the monitoring station with one being located at each of the three temperature sensor positions. Each aerovane contains an anemometer for the measurement of wind speed and a wind vane for sensing wind direction. The anemometer is a spinning rotor assembly connected directly to a generator. The rotor is propelled by the wind flowing past it and the resultant generator output is proportional to the rate at which the air is moving. The generated signal is received by a dual-channel Aerovane Recorder where it is displayed as a pen line marking on one of the channels containing a 0-120 knot chart scale. The wind vane portion of the transmitter operates in response to the direction of the wind and positions a synchronous generator which is electrically connected to a matching synchronous motor located at the recording station. The matching synchro-motor activates the recording mechanism of the dual channel recorder and a continuous record of wind direction from 0 to 360° is generated parallel to the wind speed chart.

Relative humidity of the sample air is measured before the sample is directed to the individual particle counters. Measurements are made with a wide-range humidity sensor manufactured by Hygrodynamics, Inc. The sensing of relative humidity is based on the ability of a hygroscopic film on the sensing element to change the electrical resistance of the element. The resistance change is measured by passing a constant DC current through the element and measuring the voltage across the unit. The measured voltage is seen by a transmitter which amplifies the signal and directs it to a millivolt meter from which the value is subsequently printed on paper tape. The recorded value must be referred to a predetermined calibration curve for relative humidity readings. Since relative humidity is dependent on temperature, the wide-range humidity sensing element is also equipped with a thermistor for sample temperature measurements. The signal from the thermistor is also printed on paper tape by a system similar to that described for the humidity sensor.

Barometric pressure is measured by two different methods. A microbarograph located on the eleventh floor of the Mayo Memorial building (University of Minnesota) was used to measure the longterm trends in atmospheric pressure. The instrument provides an inked recording of weekly variations in pressure. The pressure values are recorded in millimeters of mercury. A pressure transducer-converter was operated at the monitoring station and the barometric pressure was measured and recorded in equivalent millivolt values. The sensing unit of the transducer is composed of five stacked diaphragms of NiSpan-C alloy, which are mechanically linked with invar fittings to a fixed-ohm linear potentiometer. The readings from the potentiometer are converted into transmissible signals in the 0-10 millivolt range by a converter.

A recording rain and snow gage meeting U.S. Weather Bureau Specifications Nos. 450.2201 and 450.2203 was available for use in this study. The gage operated by collecting free-falling precipitation in a galvanized bucket mounted on a weighing mechanism. The weighing scale activates a pen arm which is capable of inking a scale chart attached to a rotating drum. On this chart, one inch of movement across the chart denotes one inch of rainfall.

The measurement of total sun and sky radiation was accomplished with an Eppley Pyranometer (180° pyrheliometer). This type of pyranometer consists of two concentric silver rings contained within a hermetically sealed specially-blown bulb which is filled with dry air. The inner ring is coated black and the outer ring with magnesium oxide (white in color). A thermopile is mounted directly below the two rings and, whenever the temperatures of the two rings differ, the thermopile generates a detectable signal within the low millivolt range. This signal is a measure of the radiation received by the surface of the horizontal rings and is directly related to the radiant energy in terms of cal. per cm^2 min. The signal is recorded on a Bausch & Lomb self-balancing potentiometric VOM-5 laboratory recorder. As described in the literature (46), the orientation and location of this type instrumentation is critical to the collection of valid information. Consequently, the pyranometer was located on the roof of the Mayo Memorial building to avoid interference from shadows or radiation created by vertical structures taller than the receiving surface of the pyranometer.

C. Installation and Evaluation of the Combined Particle and Meteorological System

Most meteorological and all of the particle data were collected while monitoring urban atmospheric conditions at the KSTP television tower location. As shown in Figure 11, the tower is located on the boundary between Minneapolis and St. Paul, 3/4 mile northeast of the Mississippi River and 1 1/2 miles east-southeast of the University of Minnesota. It is surrounded by industrial, commercial and residential zones and the largest topographical feature is the Mississippi River, running northwest-southeast, about 1000 feet wide and 200 feet below the base of the tower. Half a mile to the northwest is a large complex of grain-storage structures, 50-100 feet high. The area within the first few hundred yards in the east and south quadrants is characterized by large factory and commercial buildings of three to four stories. The remainder of the local area consists of two-story frame dwellings with scattered larger industrial buildings. This location was chosen because it is near the center of the St. Paul - Minneapolis metropolitan area and the thermohm and aerovane transmitters were already installed and operating at the 70, 170 and 500 foot levels of the tower.

The KSTP self-supporting tower rises from a base altitude of 904 feet to a height of 500 feet above ground. It terminates in an 83-foot transmitting mast. One leg of the tower extends through the roof of a two-story building. Adjacent to the tower leg and on the roof of the building, an 8' x 8' x 7' enclosed instrument room was constructed to house the particle counters and data-acquisition equipment used in this study. Three distinct lengths of one-inch I.D. electrical conduit were attached to the adjacent tower leg for the purpose of probing the atmosphere and transporting air samples to the instruments. Each of the three sections of conduit were attached to a common manifold in the instrument

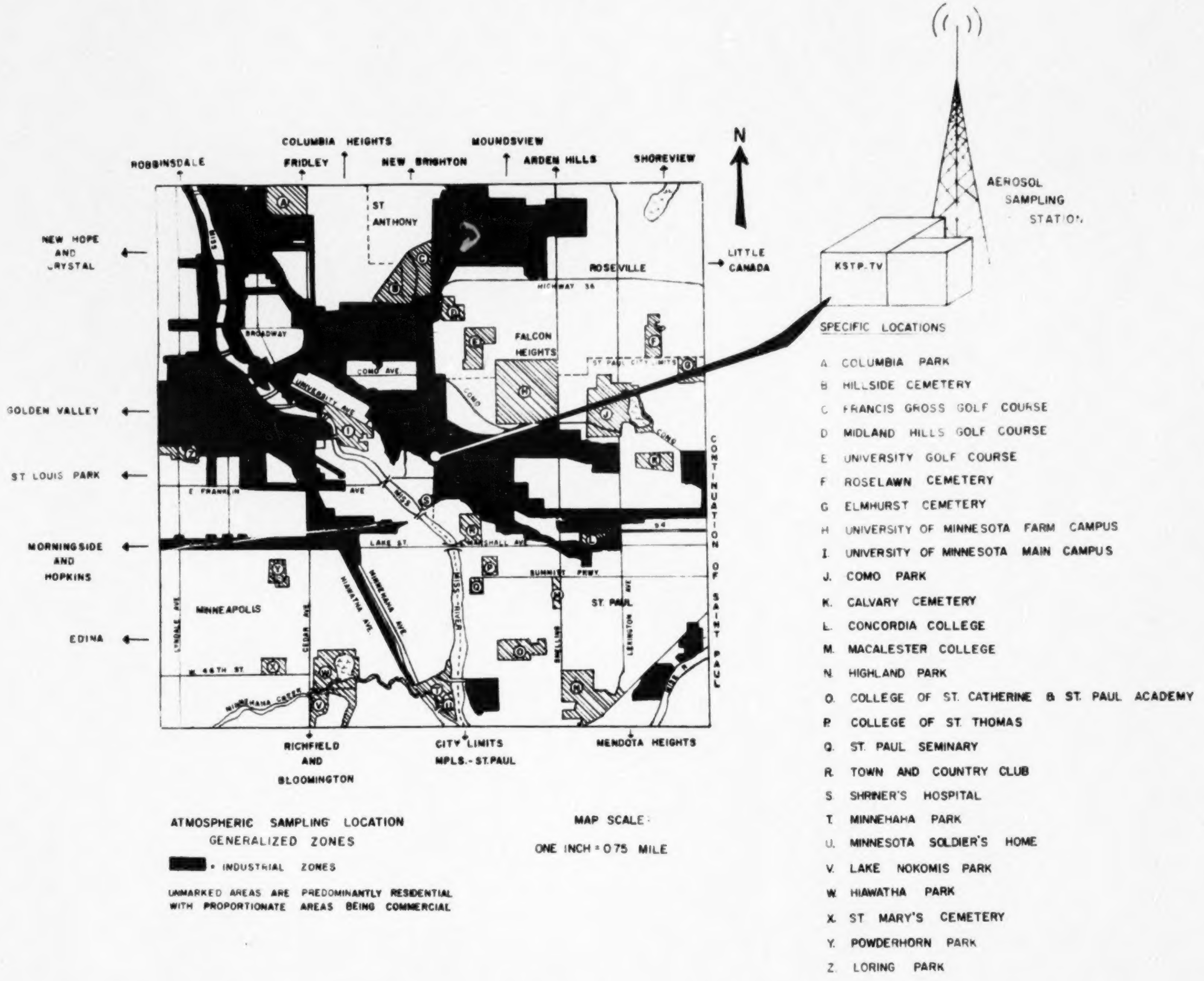

COLUMBIA HEIGHTS
MOUNDSVIEW
ROBBINSDALE
FRIDLEY
NEW BRIGHTON
ARDEN HILLS
SHOREVIEW
N
LITTLE CANADA
NEW HOPE AND CRYSTAL
GOLDEN VALLEY
ST LOUIS PARK
MORNINGSIDE AND HOPKINS
EDINA
ST ANTHONY
ROSEVILLE
FALCON HEIGHTS
MINNEAPOLIS
ST. PAUL
CONTINUATION OF SAINT PAUL
RICHFIELD AND BLOOMINGTON
CITY LIMITS MPLS.-ST.PAUL
MENDOTA HEIGHTS
KSTP-TV
AEROSOL SAMPLING STATION
ATMOSPHERIC SAMPLING LOCATION
GENERALIZED ZONES
▬ = INDUSTRIAL ZONES
UNMARKED AREAS ARE PREDOMINANTLY RESIDENTIAL WITH PROPORTIONATE AREAS BEING COMMERCIAL
MAP SCALE:
ONE INCH = 0.75 MILE
SPECIFIC LOCATIONS
A COLUMBIA PARK
B HILLSIDE CEMETERY
C FRANCIS GROSS GOLF COURSE
D MIDLAND HILLS GOLF COURSE
E UNIVERSITY GOLF COURSE
F ROSELAWN CEMETERY
G ELMHURST CEMETERY
H UNIVERSITY OF MINNESOTA FARM CAMPUS
I. UNIVERSITY OF MINNESOTA MAIN CAMPUS
J. COMO PARK
K. CALVARY CEMETERY
L. CONCORDIA COLLEGE
M. MACALESTER COLLEGE
N. HIGHLAND PARK
O. COLLEGE OF ST. CATHERINE & ST. PAUL ACADEMY
P. COLLEGE OF ST. THOMAS
Q. ST. PAUL SEMINARY
R. TOWN AND COUNTRY CLUB
S. SHRINER'S HOSPITAL
T. MINNEHAHA PARK
U. MINNESOTA SOLDIER'S HOME
V. LAKE NOKOMIS PARK
W. HIAWATHA PARK
X. ST MARY'S CEMETERY
Y. POWDERHORN PARK
Z. LORING PARK

Figure 11. Minneapolis-St. Paul area surrounding the KSTP television tower and sampling location.

room and they terminated at various heights on the tower. Termination heights were 70, 170 and 500 feet above ground level. A fourth sampling conduit extended vertically from the instrument room to a height of 45 feet above ground level. The 70, 170 and 500 foot levels were selected to permit the sampling of aerosol and measurement of wind direction, wind speed and temperature, all at the same level. A schematic diagram of the conduit arrangement is shown in Figure 12.

The joint of each conduit was sealed with silicone rubber and fitted with a special sample intake head (see Figure 12). The head was designed to permit the sampling of atmospheric contaminants from a moving aerosol cloud while preventing vertically-falling particles such as water droplets from entering the tube. The sample intake head was tested in the laboratory to determine the efficiency of sampling various-sized particles contained in airstreams traveling at different velocities. Fluorescent aerosols, ranging from sub-micron to microscopic size, were continuously generated and introduced into a wind tunnel with a known air flow rate. The air stream was sampled simultaneously with an isokinetic probe and the non-isokinetic sample intake head. The respective samples were analyzed fluorometrically and from nine experimental tests, the non-isokinetic sample fluorescence was within three percent of the isokinetic sample value when corrected to a unit volume of sample air.

The loss of particles in the air sampling conduit and related manifold system was theoretically and experimentally investigated. The results are shown in Figure 13. These losses were experimentally determined by using fluorescent aerosol generated with the Collision atomizer-impactor. This aerosol was forced through Tygon tubing to the 170 foot level where a sample was collected on Millipore filter paper contained within an inline filter holder. This resulted in a measure of the generated aerosol reaching the 170' level. The inline filter was then removed and the Tygon tubing placed into the sample intake head and the

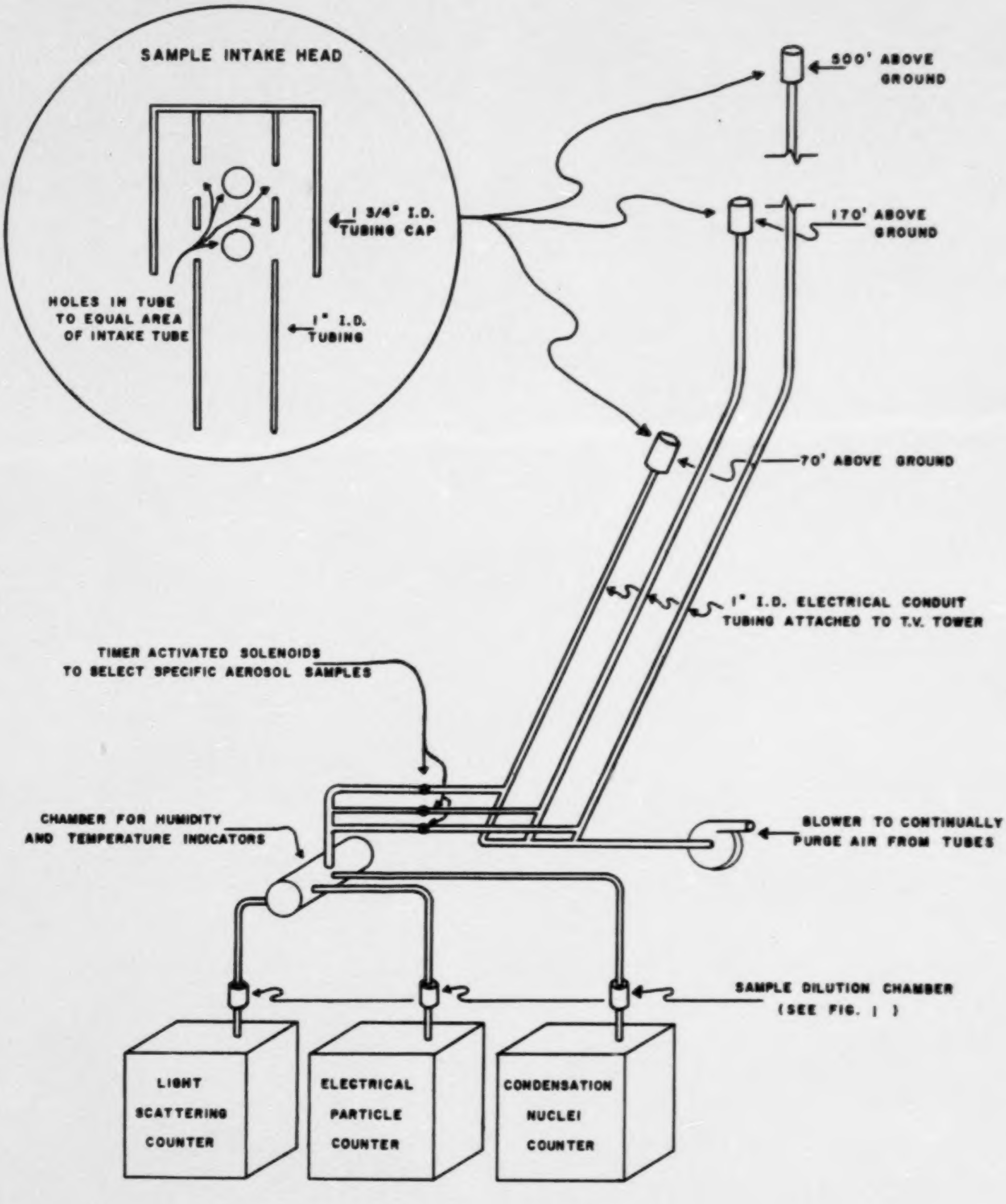

SAMPLE INTAKE HEAD
1 3/4" I.D. TUBING CAP
HOLES IN TUBE TO EQUAL AREA OF INTAKE TUBE
1" I.D. TUBING
500' ABOVE GROUND
170' ABOVE GROUND
70' ABOVE GROUND
1" I.D. ELECTRICAL CONDUIT TUBING ATTACHED TO T.V. TOWER
TIMER ACTIVATED SOLENOIDS TO SELECT SPECIFIC AEROSOL SAMPLES
CHAMBER FOR HUMIDITY AND TEMPERATURE INDICATORS
BLOWER TO CONTINUALLY PURGE AIR FROM TUBES
SAMPLE DILUTION CHAMBER (SEE FIG. 1)
LIGHT SCATTERING COUNTER
ELECTRICAL PARTICLE COUNTER
CONDENSATION NUCLEI COUNTER

Figure 12. Schematic diagram of the conduit sampling system.

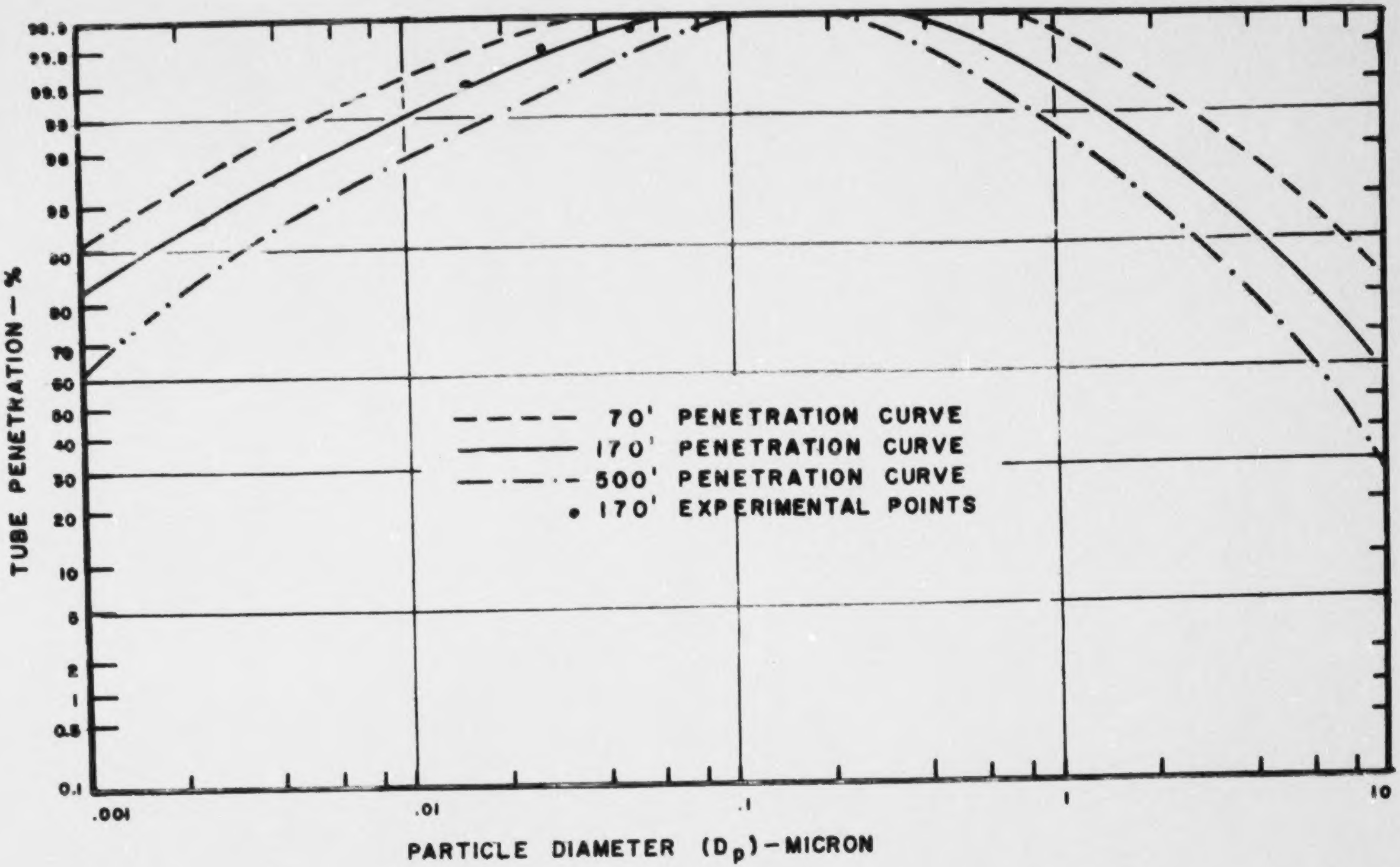


Figure 13. Results of theoretical and experimental determinations of particle losses within the aerosol sampling system.

aerosol drawn through the conduit system to the aerosol sampling manifold located in the instrument room. The aerosolized particles reaching the manifold were also filtered through a Millipore filter paper. The respective filter samples were, then, analyzed fluorometrically and, by comparing the concentration of aerosol at both levels, the penetration of particles through the tubing was determined. The results of these tests were equivalent to the theoretical results obtained by summing the calculated losses due to particle diffusion and sedimentation. The theoretical diffusion losses were determined from equation 11 developed by Fuchs (47), and sedimentation losses were calculated by equation 12 which was formulated by Thomas (48).

$$\bar{N} / N_o = 1-2.56\mu^{2/3} + 1.2\mu + 0.177\mu^{4/3} \qquad (11)$$

$$\bar{N} / N_o = (2 / \pi)\ (\alpha\ \beta + \sin^{-1}\beta - 2\alpha^3\beta) \qquad (12)$$

Where $\bar{N}/N_o$ = fractional component of the total particles which penetrate the tubing.

$\bar{N}$ = number of particles penetrating the tubing.

N_o = initial number of particles entering the tubing.

$\mu = DX/R^2\ \bar{U}$ [dimensionless]

$\alpha = (3LZ/8\bar{U}R)^{1/3}$ [dimensionless]

$\beta = (1 - \alpha^2)^{1/2}$ [dimensionless]

D = diffusion coefficient, ft^2/min.

X = actual length of tubing, feet.

R = radius of tubing, feet.

$\bar{U}$ = average gas velocity in tubing, feet/min.

L = horizontal length of tubing, feet.

Z = settling velocity of particle, feet/min.

Assumptions made in the determination of theoretical losses were that the air temperature was 60° F., the apparent particle density was 2.0 grams per cubic centimeter and that the sample air velocity in the conduit was maintained at a constant rate. With an assumed average air velocity of 175 ft/min., the pipe Reynolds number was 1500. The physical dimensions of the system are listed as one inch I.D. conduit with horizontal lengths of 0, 8, 15.5 and 40.5 feet for the respective sampling lengths of 45, 70, 170 and 500 feet.

In operation, air was continually drawn through each length of conduit. This prevented the sampling of stagnant or aged aerosol during the initial sampling period from any level. During the nonanalysis period, air flow through each conduit was equal to the established sampling flow rate minus the sample air drawn by the three particle sizing and counting instruments. The residual airflow rate is maintained by a Hoffman Industries centrifugal blower located downstream of the sampling manifold. The flow is regulated by globe-type valves and is monitored with a Magnehelic gage and orifice assembly.

An in-service operational check of the Royco and EPC particle counters was routinely performed by noting the number of particles counted by each instrument in the particle size range from 0.5 to 1 micron. When the instruments are operated simultaneously and adjusted to count the particles within this same particle size interval, the counts should be equivalent in magnitude when each instrument is operating properly. If discrepancies arise, the validity of the data must be questioned, the proper operation of the instruments checked, or the applied sampling methods investigated. In general, duplication of counts was within the experimental accuracy of the test apparatus (i.e., 20 percent accuracy). A similar check between the nuclei counter and the EPC was not possible since the two counters were not capable of determining particle number within a size range of equal width. In fact, the number of particles in the 0.001 to 0.01 micron size range was determined by subtracting the number of particles indicated by the EPC over the range from 0.01 to 0.1 micron from the count obtained by the condensation nuclei counter in the size range from 0.001 to 0.1 micron.

CHAPTER IV

DATA COLLECTION AND REDUCTION

The total instrumentation functions to provide a continuous monitoring of particle size, particle count, relative humidity, temperature, barometric pressure, horizontal wind speed and direction, total radiation, precipitation, smoke spot characteristics and equivalent SO_2 concentrations. Particle size and count, temperature, wind speed and wind direction are measured at three elevations and all other parameter values are sensed at or near ground level.

During a ten-minute automatic sampling period, the particle sizing and counting instruments display 118 bits of information from which the number of particles within thirteen different size ranges may be determined. The particle count and size data, as well as sample air temperature and relative humidity, are recorded directly in digital form. Particles counted by the light scattering particle counter are enumerated and printed on a single paper tape. All other signals, printed as digital values, appear on a second paper tape and are printed in terms of millivolt values reduceable to respective measured parameters. Data reduction of the digital values begins by summing and averaging the signals which are a measure of a specific parameter and recorded more than once during a basic sampling period. The repeated measurement of certain parameters was designed into the system to obtain a statistically reliable reading of those parameters which might fluctuate during a relatively short sampling period. Upon averaging the signals, appropriate meter and scaling factors are applied to the basic signal values to obtain readings indicative of the respective functions being measured. The values are inserted into specific equations to calculate the number of particles present in a cubic centimeter of sample air within certain particle size ranges.

Wind speed and direction, precipitation, ground level barometric pressure, relative humidity and radiation are continuously recorded on chart paper and appropriate time-dependent data are read to correspond to the particle sampling periods. The temperature measured at respective levels are plotted on chart paper every two minutes. Equivalent SO_2 concentration in the atmosphere is measured on a ten-minute sampling cycle with a Scientific Industries SO_2 Analyzer/Recorder. This instrument detects the presence of SO_2 by oxidation of the gas to H_2SO_4 and measurement of the change in electroconductivity of the detection liquid. Every ten minutes fresh reagent is introduced into a detecting cell and during the sampling period, sample air impinges onto the surface of the reagent. The SO_2 present in the air reacts with the reagent and changes the conductivity of the solution. The conductivity change is continuously recorded and reduced to SO_2 concentration in terms of ppm.

Soiling characteristics of the atmospheric aerosol are continuously monitored with a Research Appliance Corporation Smoke Spot Analyzer/Recorder. The measurement is based on the change in light transmission through a filter paper that is positioned to filter a stream of sample air at a fixed airflow rate. A particular filter area is exposed to the air stream for two hours and the change in light transmission through the filter paper due to the accumulation of particulate matter is continuously measured photoelectrically. The paper chart recordings are reduced to COH factors (coefficient of haze).

The collection of particulate material for microbiological analysis was accomplished with two different types of samplers. The Casella slit sampler (model T 13648/1) was used to detect the concentration of viable organisms at various elevations. An Anderson, which operates on the principle of varying-impaction velocities, was used to classify the particulate matter into approximate size ranges of $<$ 1μ, 1-2μ, 2-3μ, 3-6μ, 5-10μ and > 8μ. Both of these devices sample the air at a fixed rate of 1 cfm and deposit the particulate matter directly on a nutrient surface. The viable contaminants thus collected proliferate "in situ" and produce visible colonies that can be counted.

Typticose Soy Agar was the basic nutrient medium used. This medium appeared to be relatively non-selective, permitting the growth of a variety of organisms. However winter sampling required the addition of carboxymethylcellulose ether to prevent the adverse effects of freezing on the agar media.

The agar plates exposed in either the Anderson or Casella samplers, were incubated generally about 96 hours. The incubation temperature was room temperature because this was more suitable for the culturing of the various types of microorganisms naturally occurring in the atmosphere. The number of colonies was counted using a New Brunswick Scientific Instrument Co., Model C-1100, colony counter. During the counting, colonies morphologically identifiable as molds were enumerated separately. The viable collections reported are presented in terms of colony forming units per cubic foot (CFU/ft^3). This corresponds to the number of colonies counted per plate divided by the amount of air sampled. A drawback of direct collection on a nutrient surface, common to both of the two types of samplers used, is the necessity to collect a suitable number of viable particles, not too numerous to count but still enough so they can be distinguished from the background contaminations. Further dilution or concentration was impossible so it was necessary to examine the counts obtained during the past several sampling periods and adjust the length of sampling time so the expected counts would be in the proper range.

Samples were obtained from four elevations: 35, 70, 170 and 500 feet above the grade level. At the 35 foot level, the samplers were placed directly on the television station's roof, while at the other elevations the samplers were attached to the sampling tubes which extended along the television tower. During each run, samples were obtained simultaneously from each elevation and two or three duplicate runs were carried out in each sampling day. It was calculated that about 1% of the 1-μ diameter particles are lost in traveling through the tube from the 500 foot level. For an 8-μ particle the percentage increased to about 50. At the lower elevations, 70 and 170 feet, the losses in the sampling tubes were less;

only for particles larger than five microns did they exceed 10%.

The array of numbers generated in the systematic determination of a single number-size distribution is illustrated in Table IV. The data for this illustration were obtained with the wide spectrum particle counting system sampling from the 70-foot level during the time 1128 hours to 1138 hours on February 6, 1967. The preset particle sensing size ranges are indicated in column 1 of Table IV. The large particles (0.5 to > 4 microns) are sensed by the light scattering particle counter and the number of such particles in the various size ranges are recorded directly in terms of the number sensed per gas volume flow rate through the detector (column 9). The recorded numbers are reported as particles per cubic centimeter sample air (column 12) and these numbers are further adjusted to account for particle losses in the sampling tube and dilution air added to the sample volume. The values which account for these conditions are listed in columns 5 and 6, respectively.

Particles within the size range of 0.01 to 0.5 micron are detected by the EPC. When filtered, these particles impart a measureable current to the filtration system and by controlling, in specific increments, the size of particles being filtered, a series of current values are obtained (column 10). The voltage applied (column 7) determines which sized particles are removed from the sample air stream to the collecting rod and which are filtered from the sample air. The appropriate voltage to be applied is predetermined and is a function of the respective electrical mobility of the particles and gas volume flow rate through the sampler. The resultant current values decrease as the applied voltage increases and increasingly larger-sized particles are collected before filtration. The differences between succeeding current measurements (column 11) are inserted into equation 13 to determine the basic number of particles per size range measured with the EPC.

SIZE INFORMATION			COMMON SYSTEM INFORMATION					MEASURED DATA				CALCULATED DATA			RESULTS	
PARTICLE LIMIT D_p-μ	PARTICLE MIDPOINT D_{pi}-μ	PARTICLE INTERVAL ΔD_p-μ	ELECTRICAL MOBILITY CM/SEC/CM/VOLT	PARTICLE CHARGE n_p	ANALYZER EFFICENCY K - %	TUBE PENETRATION η - %	% DILUTION AIR FACTOR	COLLECTION VOLTAGE -VOLTS-	NUCLEI COUNT NO/CM^3	OPTICAL COUNT NO/FT^3	FILTER CURRENT $I \times 10^{12}$ -AMPS	$\Delta I \times 10^{12}$ -AMPS-	Δ NO NO/CM^3	Δ NO (CORRECTED) NO/CM^3	RELATIVE FREQUENCY NO/CM^3 ΔD_p	PLOTTED AT D_p, μ
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
.002																
	.006	008				99.75	40.3		116,670 → INCLUSIVE OF PARTICLES FROM 0.002 TO 0.1 μ	CORRECTED FOR DILUTION AIR AND 0.002 TO 0.1μ RANGE →			104,391	104,853	1.3×10^7	.006
01			.0226					260			11.82					
	.015	01		1.23	44	99.85	0					1.32	41,989	42,052	4.21×10^6	.015
.02			.0067					877			10.50					
	.025	.01		1.45	75.	99.9	0					0.924	14,808	14,622	1.46×10^6	.025
03			.00399					1,473			9.576					
	.035	.01		1.83	86.	100.	0					0.696	7,600	7,600	76×10^5	.035
.04			.00272					2,161			8.88					
	.05	.02		2.43	91.5	100	0					2.06	15,592	15,592	7.79×10^5	.05
.06			.0017					3,457			6.864					
	.07	.02		2.89	94	100.	0					1.776	11,242	11,242	5.62×10^5	.07
.08			.00127					4,628			5.088					
	.09	02		3.48	95.	100	0					1.992	10,362	10,362	5.18×10^5	.09
.10			.00102					5,762			3.096					
	.15	.1		5.5	96.1	100	0					2.346	7,634	7,634	7.63×10^4	.15
.20			.00085					9,112			.75					
	.25	.1		9.2	97.5	100.	0					.502	962	962	9.82×10^3	.25
.30			.00054					10,904			.248					
	.4	.2		14.75	98	100.	0					.169	201	201	1.01×10^3	.4
.50			.000464					12,665			.079					
	.75	.5				99.9	40.3			4,540			2.87	2.87	5.74	.75
1.0			.000407													
	1.5	1.0				99.6	40.3			622	DILUTION FACTOR APPLIED AND CONVERTED TO NO/CM^3 →		.56	.56	.56	1.5
2.0																
	3.0	2.0				98.5	40.3			194			.12	.12	.06	3.0
4.0																
	6.0	4.0				94.0	40.3			7			.004	.004	.001	6.0
>4.0																

Table IV. Data format for the calculation of a particle number-size distribution.

$$N_o = \Delta I / (e\, n_p\, Q_a) \qquad (13)$$

Where:

N_o = number of particles detected within a specific size range, particles per cubic centimeter

ΔI= difference in filter current readings as calculated from current readings obtained when increasingly larger voltages are applied to the EPC collecting rod, amperes

e = elemental ion charge, 4.8×10^{-10} stat coul.

n_p = number of unit ion charges per particle

Q_a = aerosol flow rate through the EPC, cm^3/sec.

The particle number is adjusted for loss of particles within the EPC and to compensate for the calculated percentage of small particles which do not acquire a charge while passing through the diffusion charger of the EPC. The instrument efficiency factor (column 4) accounts for both of these corrections. Particle losses in the sample tubing are accounted for by applying the tube-penetration factor (column 5).

As previously indicated, the particle concentration in the range from 0.001 to 0.01 micron is determined by subtracting the number of particles detected in the range from 0.01 to 0.1 micron with the EPC from the total number of particles sensed by the condensation nuclei counter which includes all particles in the sample air ranging in size from 0.001 to an upper limit of 0.1 micron. Before subtraction, the nuclei count is adjusted for dilution air added to the sample air flowing through the nuclei counter and for particle losses in the sample tubes.

The total number of particles detected in each size range are tabulated in column 13. However, the magnitudes of these numbers are not a true indication of frequency or number of particles per respective particle size as the values are counts of particles which are contained in class intervals of varying widths. Therefore, the numbers in column 13 are divided by the respective size range width (column 3) and relative particle frequency numbers (column 14) with units of particles per micron size are obtained.

The relative particle numbers per size are true indicators of the number of particles of a given particle size and the data are directly applicable to such studies as aerosol aging phenomena, evaluating particulate respiratory loading characteristics of the environment or the variation in particle numbers during different meteorological conditions. Graphical presentations of the relative particle numbers present in the aero-environment are generally in the form of a relative number-size frequency distribution curve obtained by plotting the relative number data (column 14) as a function of some particle size within each sizing range (column 2). The relative particle number-size frequency curve resulting from the data of this example is shown in Figure 14.

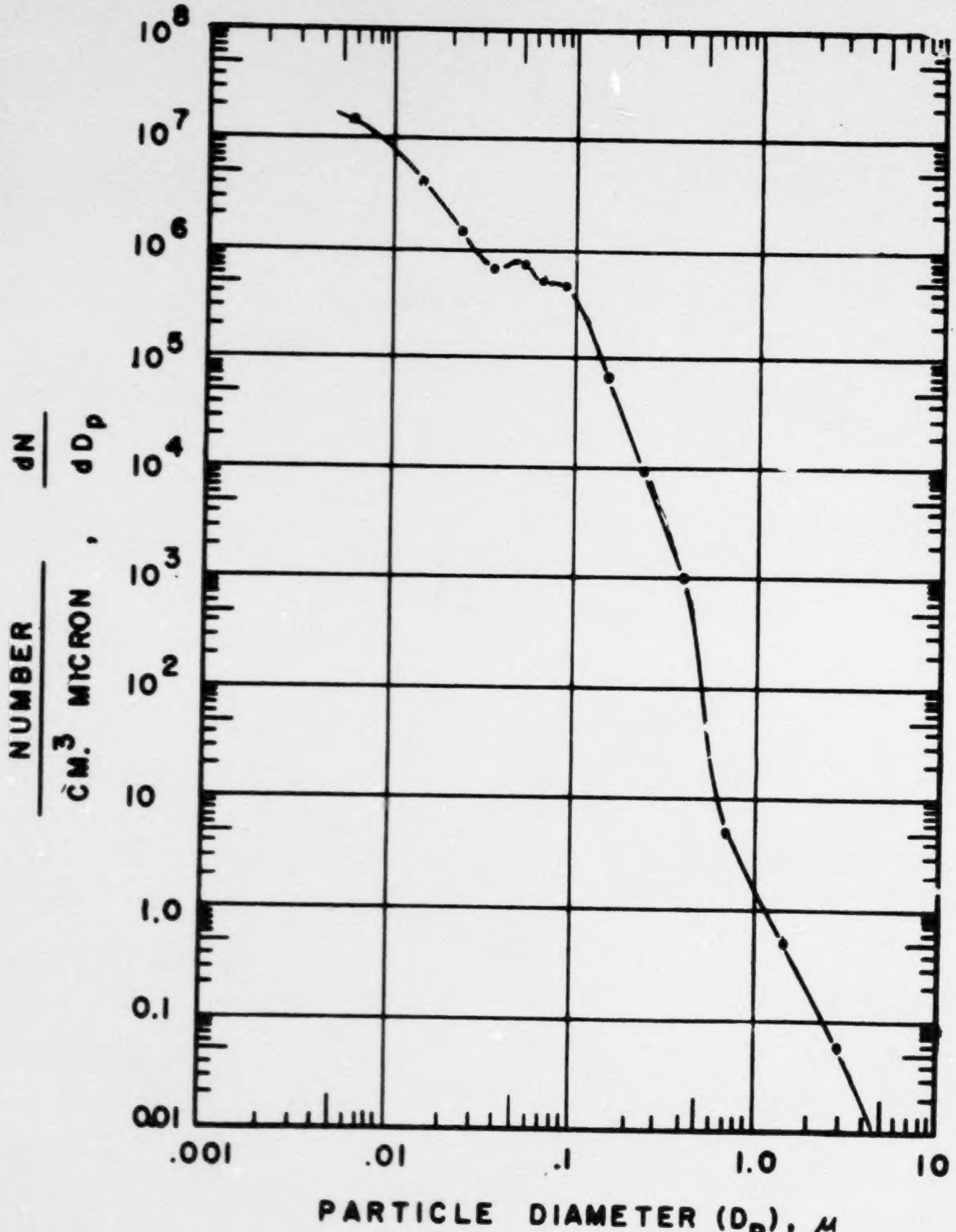


Figure 14. Relative particle number-size frequency curve obtained from sample calculations.

CHAPTER V

PRESENTATION, INTERPRETATION AND ANALYSIS OF METEOROLOGICAL AND PARTICLE DATA

A tabulation of particle and meteorological data obtained while automatically monitoring the aero-environment are presented in Appendix A and B respectively. The data are presented (1) to show the value and feasibility of continuously and simultaneously monitoring atmospheric particle and meteorological conditions, (2) to investigate particle and meteorological parameter interactions, (3) to experimentally investigate the conformity of urban aerosol particle number-size distributions to the proposed distribution which results when the particles obey a self-preserving phenomenon.

The data includes three hundred and sixty particle number-size distributions, equivalent SO_2 concentration measurements, smoke spot evaluations and various meteorological parameter measurements. Meteorological parameter values are inclusive of wind speed and direction, vertical temperature measurements, precipitation, relative humidity, barometric pressure and total direct radiation. Specific days for which sampling data are compiled include 6 February 1967, 7 February 1967, 22 February 1967, 12 July 1967, 13 July 1967, 19 July 1967, 20 July 1967 and 27 July 1967. The data from these days were selected on the basis of either varied or unique vertical temperature distributions, wind speed or direct radiation conditions.

The particle and meteorological data tabulated in Appendix A and B are interpreted and analyzed as per the previously stated study objectives. Statistical analysis is not used in the interpretation of the results as the quantity of data collected to date is not sufficient to establish statistical significance and the method of selecting the tabulated data negates the use of statistical correlations. The tabulated data were selectively chosen to prove the value of a continuous particle-meteorological monitoring system and to permit the determination of particle number-size distributions which exist during the occurrence of specific meteorological conditions. The lack of statistical analysis does not alter the tabulated results or the study objectives for as discussed the data do show various particle behavior patterns which may repeatedly occur during certain meteorological conditions. The occurrence of such behavior patterns remain to be statistically proven as these data only establishes the possibility of such phenomena and the need for additional research.

A. Graphical Presentation of Meteorological Data

It was readily apparent from the quantity of particle-meteorological data available that including information from all monitoring periods was objectively not realistic. Therefore, the recorded values of all parameters measured during particle monitoring periods were reviewed and only sampling intervals within which select meteorological conditions existed were selected for investigation. Both winter and summer sampling periods were chosen.

1. Meteorological Data Collected During Winter Sampling

Temperature and wind speed conditions on 6, 7 and 22 February 1967 satisfied the meteorologic selection criteria for winter monitoring periods. The wind direction, wind speed and temperature distribution values for these days are graphically presented according to the time of monitoring in Figure 15. A temperature inversion occurred on both 6 and 7 February. It is this parameter which is considered dominant in analyzing the particle number-size data of this period. In Figure 15 the periods during which the temperature inversion was detected below the 500 foot level are noted by the shaded area of the temperature difference curve denoted as $T_{500} - T_{70}$. An adiabatic to super-adiabatic temperature lapse rate was maintained for a period of time on 22 February and the data were reviewed to investigate particle behavior during this type temperature distribution.

Figure 15 also shows that wind speed variations were present during the sampling days being reviewed. However, 6 and 7 February are basically low wind

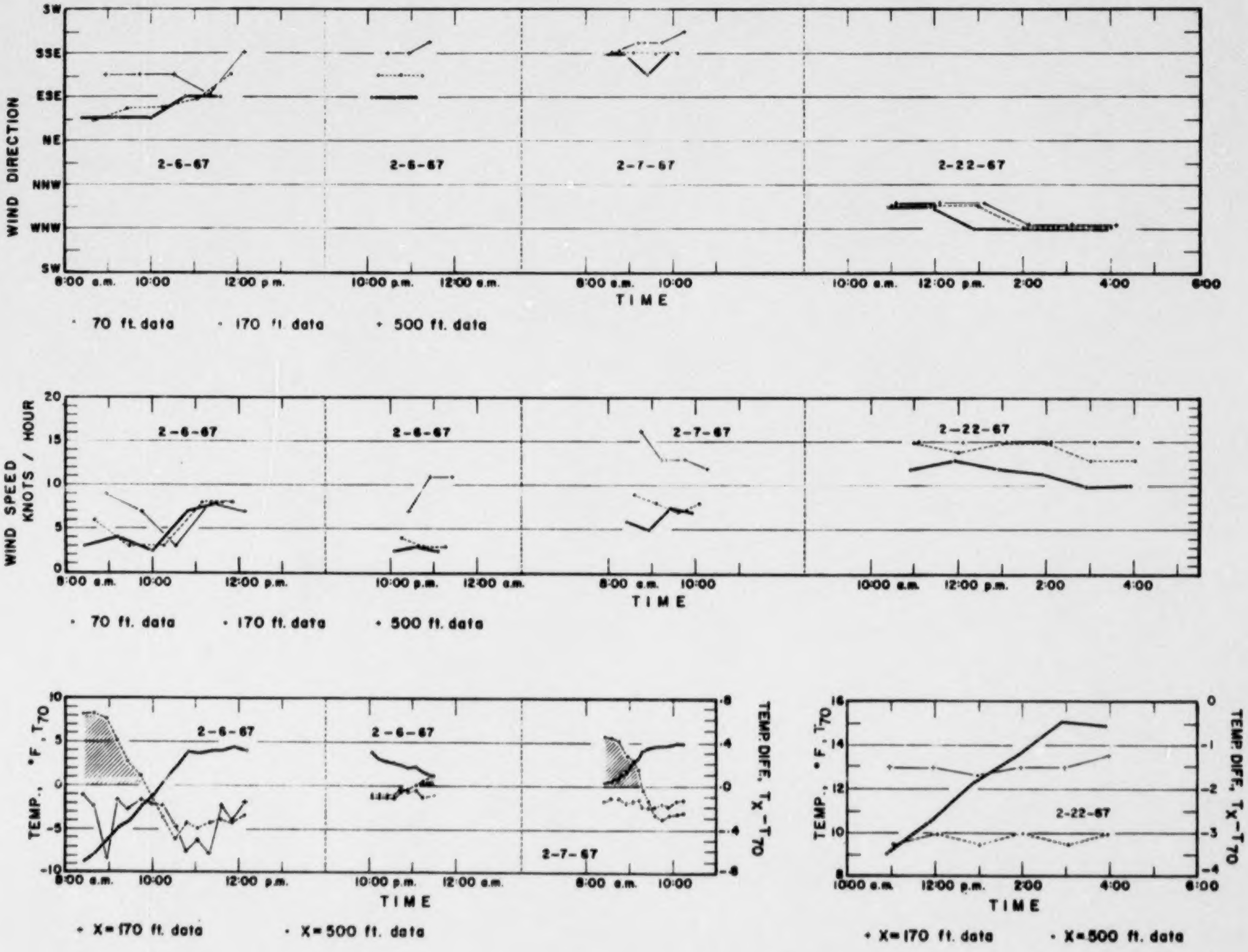


Figure 15. Wind direction, wind speed and temperature distribution values for the winter sampling periods.

speed days and the sample period on 22 February was characteristic of high wind speeds.

The relative humidity not only varied between specific sampling periods but also during each sampling period. This phenomenon is not desirable when investigating the particle behavior associated with temperature but variations in air temperature are most always reflected in the relative humidity values.

2. Meteorological Data Collected During Summer Sampling

The selection of a limited number of summer sampling periods was more difficult as additional parameters were measured during these periods and within each specific parameter there appeared to be less variation. However, July 12, 13, 19, 20 and 27 of 1967 were chosen on the basis of specific meteorological parameter values.

The values recorded during the monitoring of meteorological parameters on July 12 and 13 were typical of summer time readings except for the low maximum and minimum air temperatures. A temperature distribution which ranged near adiabatic, a high wind speed and significant short-term variations in direct radiation were the meteorological phenomena of interest.

The temperature variation occurring at each monitoring level during the sampling period is shown graphically by Figure 16. This Figure also contains a graphical presentation of the measured wind direction and speed. It is seen from Figure 16 that the typical diurnal temperature variation was established, that inversion conditions never occurred below the 500 foot level and that a strong negative lapse rate supposedly capable of inducing highly unstable air masses was predominant.

The wind speeds shown in Figure 16 indicate that high air velocities prevailed at all levels and increased with height. Air movement did decrease slightly as the sampling period extended into 13 July. Wind directions were steady at all levels ranging from the west-north-west through the northern sector.

Smoke spot and direct radiation determinations for 12 and 13 July as

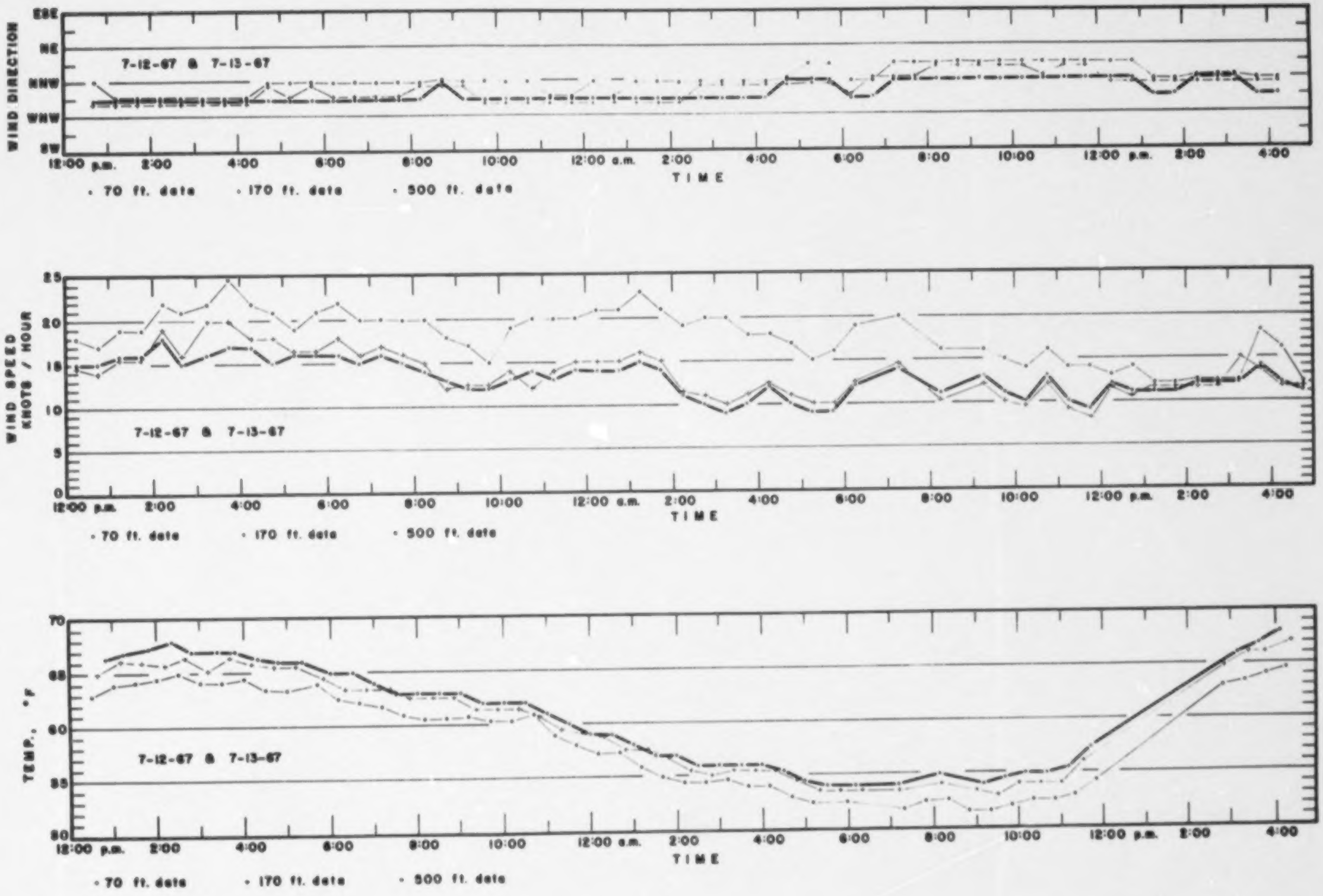


Figure 16. Wind direction, wind speed and temperature distribution values plotted for the summer sampling period-12 and 13 July 1967.

well as the variation in reported values are shown in Figure 17. Smoke spot values are not an evaluation of a meteorological parameter but are included as part of the data used in selecting sampling periods for review as the readings are an indication of the level of particulate concentration within the atmosphere.

Direct radiation values are ten minute averages calculated from the continuous recording generated primarily by the absorption of direct radiation energy by the surface of the pyreheliometer. These radiation values are particularly important during this sampling period as they vary widely and the low average values are indicative of time periods when scattered sky cover passed directly between the sun and detector. The measured reduction in direct radiation is a parameter in the relationship between photo-particle reactions and changes in atmospheric particle number or size.

July 19 and 20 were the days of the second sampling period selected for particle data interpretation and analysis. A summer temperature inversion, low wind speeds below 170 feet and high wind speed at the 500 foot level and high and low radiation measurement values were factors in favor of the selection of this sampling period. In addition, the late afternoon and early evening sample period of 20 July was included for a review of measurements taken directly after a short period of scattered precipitation.

Measured temperature, wind direction and wind speed values and the variation within each during the sampling period of 19 and 20 July are graphically shown in Figure 18. The temperature variation was greatest at the 70 foot level and least at the 500 foot point. This resulted in the formation of a temperature inversion below the 500 foot level during the hours 1045 July 19 to approximately 0800 July 20. During this inversion a large variation in wind speed with height was also measured and the influence each meteorological parameter exerts on the changing particle number-size distribution is impossible to determine at the present time. As shown by Figure 18 the 70 and 170 foot air velocities are generally in

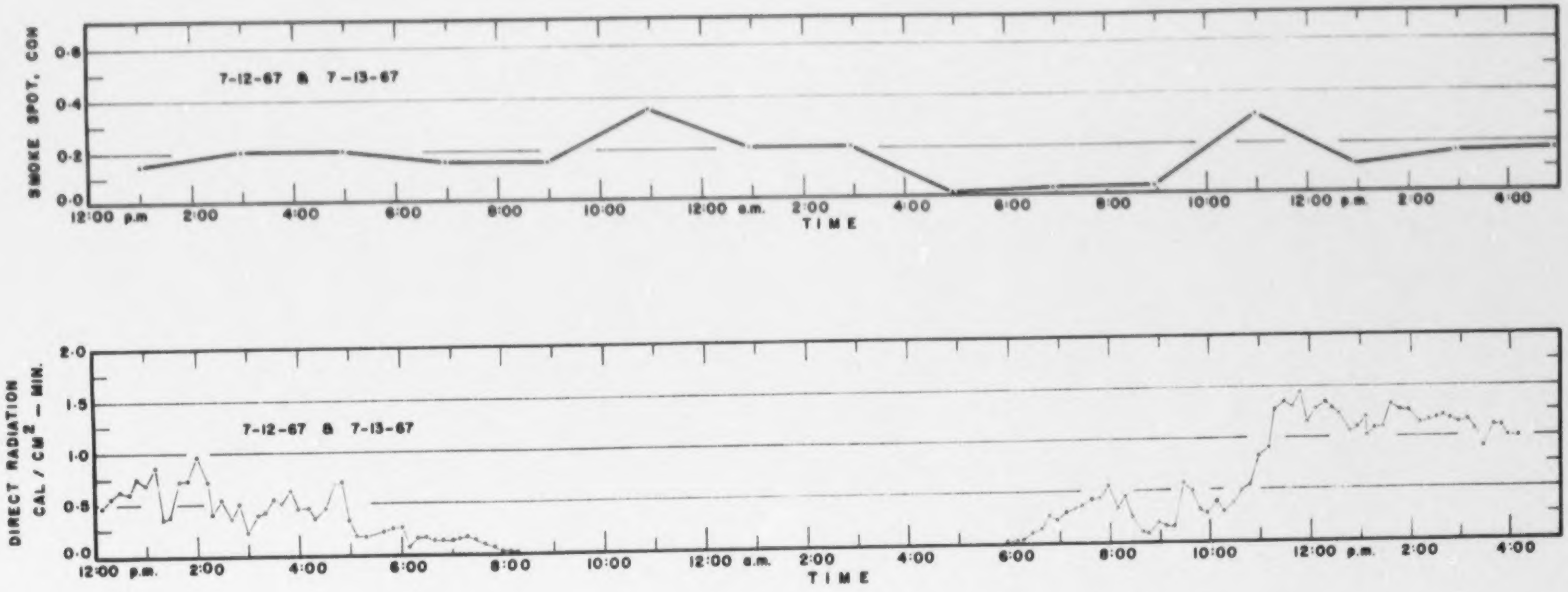


Figure 17. Variation in smoke spot and direct radiation measurements during the summer sampling period-12 and 13 July 1967.

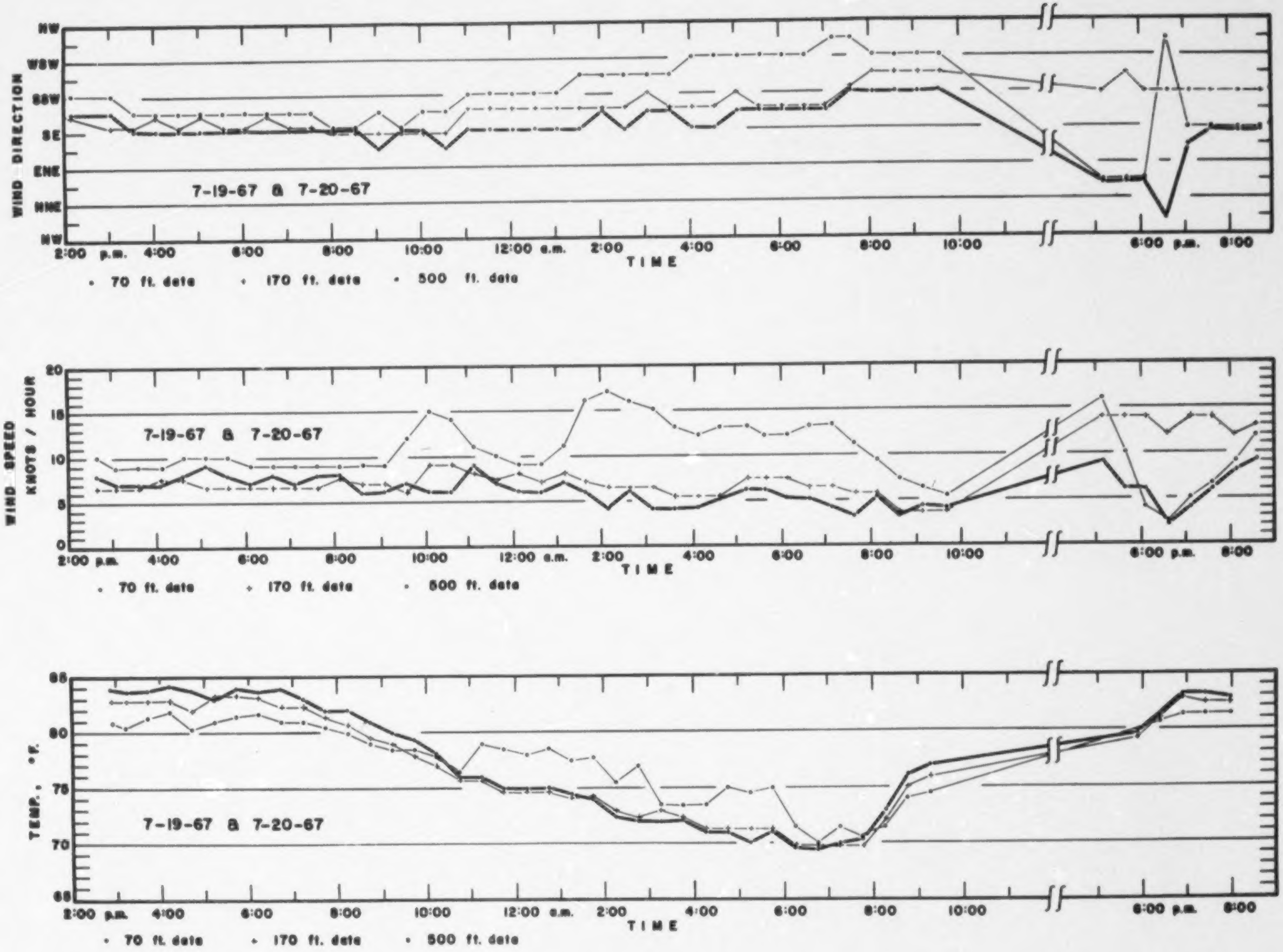


Figure 18. Plot of wind direction, wind speed and temperature for the summer sampling period-19 and 20 July 1967.

the range of low wind speeds and the air at the 500 foot level was monitored at values as high as 17 knots per hour.

SO_2, smoke spot and direct radiation values for 19 and 20 July are presented in Figure 19. The SO_2 and smoke spot values are the results of atmospheric samples drawn from the 45 foot level. The SO_2 values represent 10 to 15 minute averaging concentration results and as such are indicative of short time variations in the concentration of the gas measured. It will be noted that there is considerable variation in SO_2 measurement values shortly before the temperature inversion was detected.

The smoke spot values are the results of two hour sampling periods and are not directly related to short term particle number-size measurements. However, the time period of sampling is sufficiently short to show the general increase in atmospheric soiling properties during the temperature inversion period.

The graphical presentation of radiation values readily shows the sharp decrease in measured direct radiation at approximately 1645 on 19 July and the gradual increase which corresponds to the beginning of daylight hours on 20 July. This gradual increase is typical of clear sky conditions.

The data resulting from the measurement of the meteorologic parameters, SO_2, smoke spot and total particle counts are graphically presented for the sampling period of 27 July 1967 in Figure 20. The near adiabatic temperature lapse rate, low wind speed and non-variant direct radiation measurement values were major reasons for the selection of this sampling period.

The 170 foot wind fluctuated throughout the north to east-north-east sector during most of the monitoring period but toward the end of the sampling period changed to the northwest and westerly directions. The effect of this change on the measured particle number-size distribution cannot be evaluated. This was the only major meteorologic parameter which showed a significant undesirable

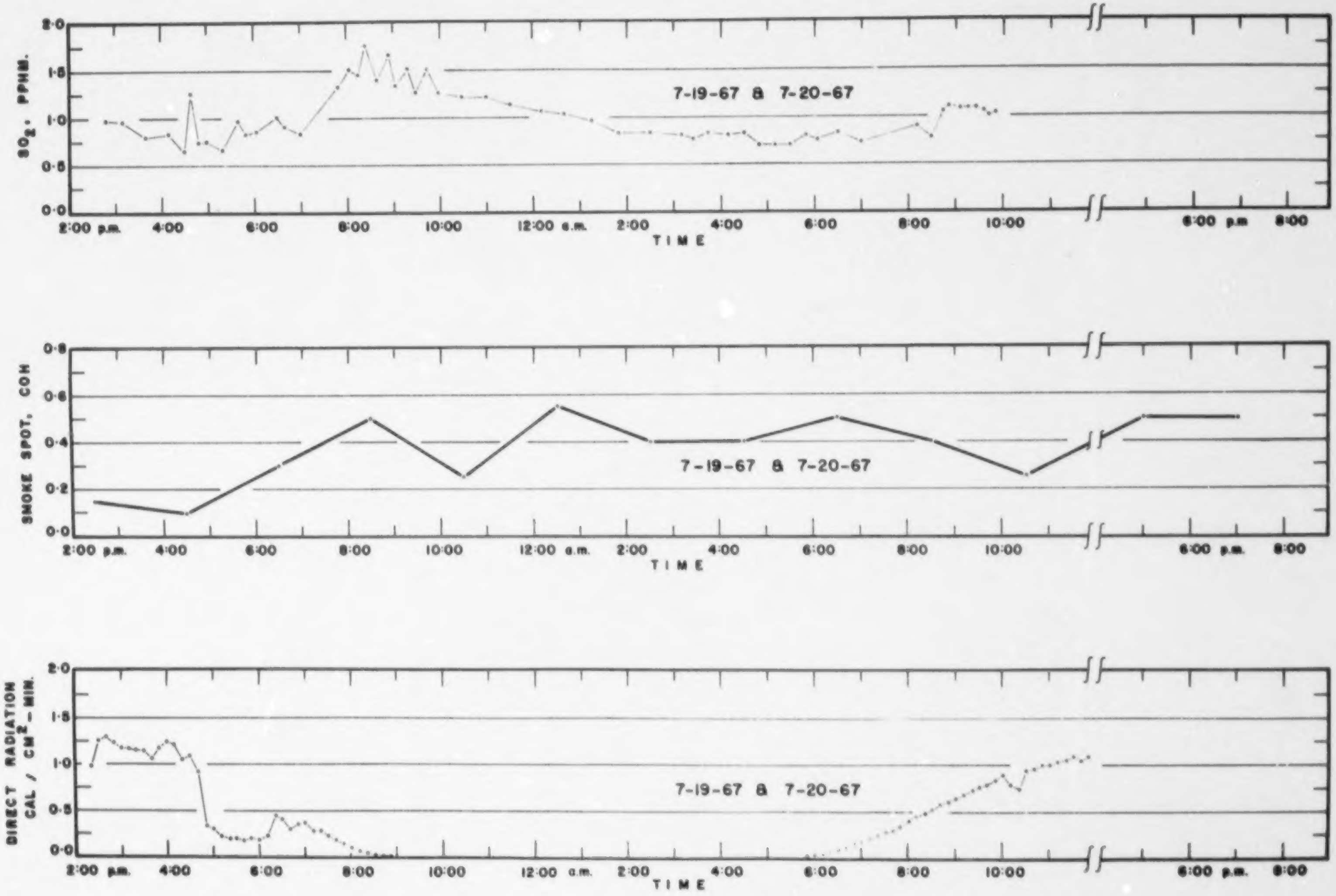


Figure 19. Plot of smoke spot, direct radiation and SO_2 values for the summer sampling period- 19 and 20 July 1967.

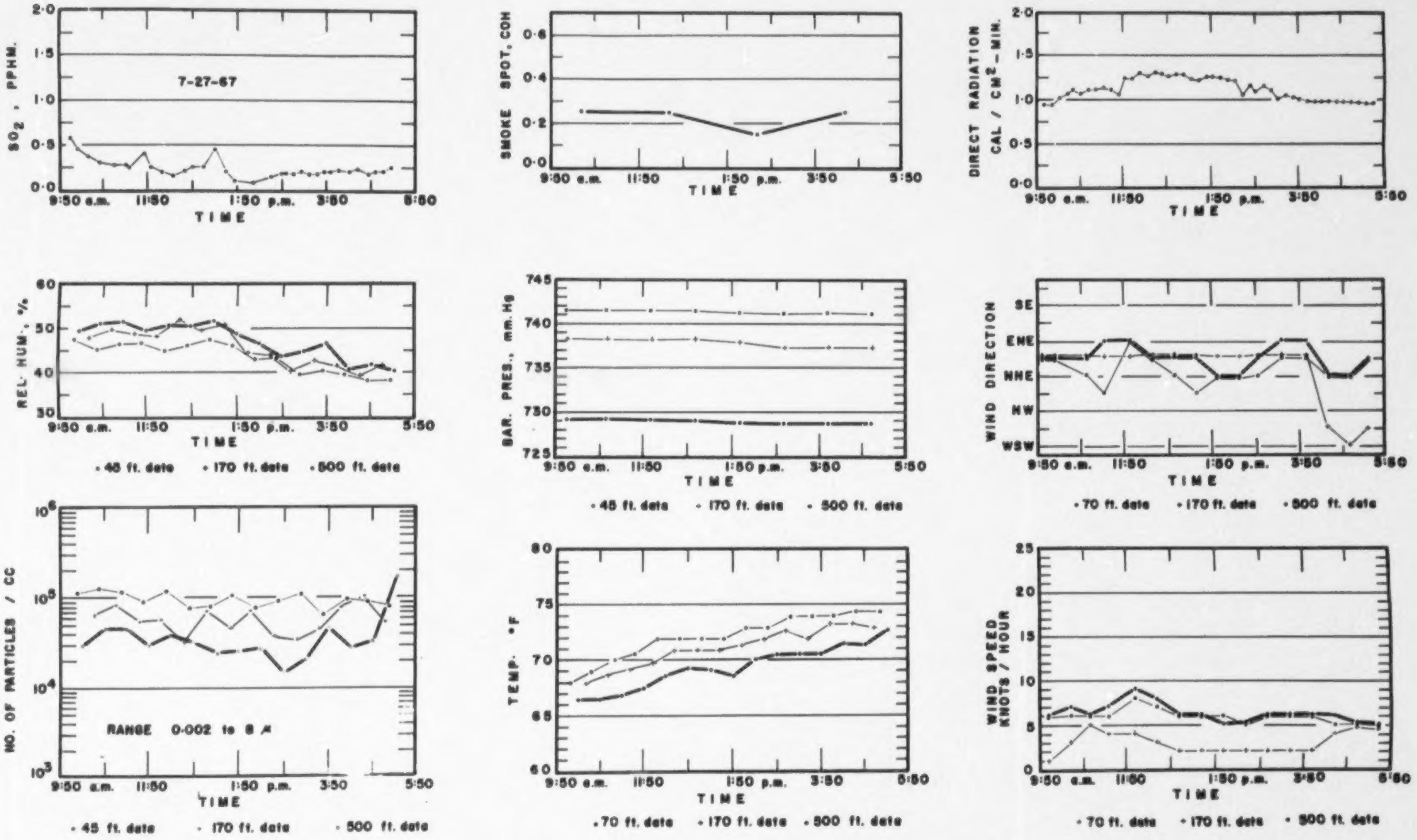


Figure 20. Plot of meteorologic and particle data measured during the summer sampling period-27 July 1967.

variation.

B. Graphical Presentation of Particle Data

The particle data are graphically presented in terms of number of particles counted with reference to the monitoring time. Figures 21, 22 and 23 contain the results of winter particle sampling and Figures 24 through 30 include particle results of summer sampling periods.

As presented, the figures associated with each sampling period are a graphical presentation of the particle number concentration measured at the 70 (or 45), 170 and 500 foot levels. The first figure of each group is a presentation of the 70 (or 45) foot level data. The second and third figure are respectively devoted to the presentation of particle information as obtained at the respective 170 and 500 foot sampling levels. An identical procedure was followed in tabulating and presenting the data contained in the first three figures of each sampling period. Hence, the array of figures may be reviewed separately or as a composite group. Each figure contains a number of unique straight lines drawn between specific data points. Each data point represents the number of particles per cubic centimeter of sample air measured at a particular time as designated by the absicssa. The array of data points which are interconnected by straight lines represent the number of particles counted within a specific size range. The size range always extends from a lower size limit which is noted on the graph to the largest particle size detected with the available instrumentation. Therefore, the lowest line of the graph is characteristic of large particle behavior and each succeeding line drawn is inclusive of all measured particles larger than the designated lower particle size limit for the respective line. The upper most line characterizes the total number concentration of particles counted and the time dependent variations which occurred during the sampling period. Each line on the graph should be reviewed with reference to the next lower line which represents a smaller size range and consequently a

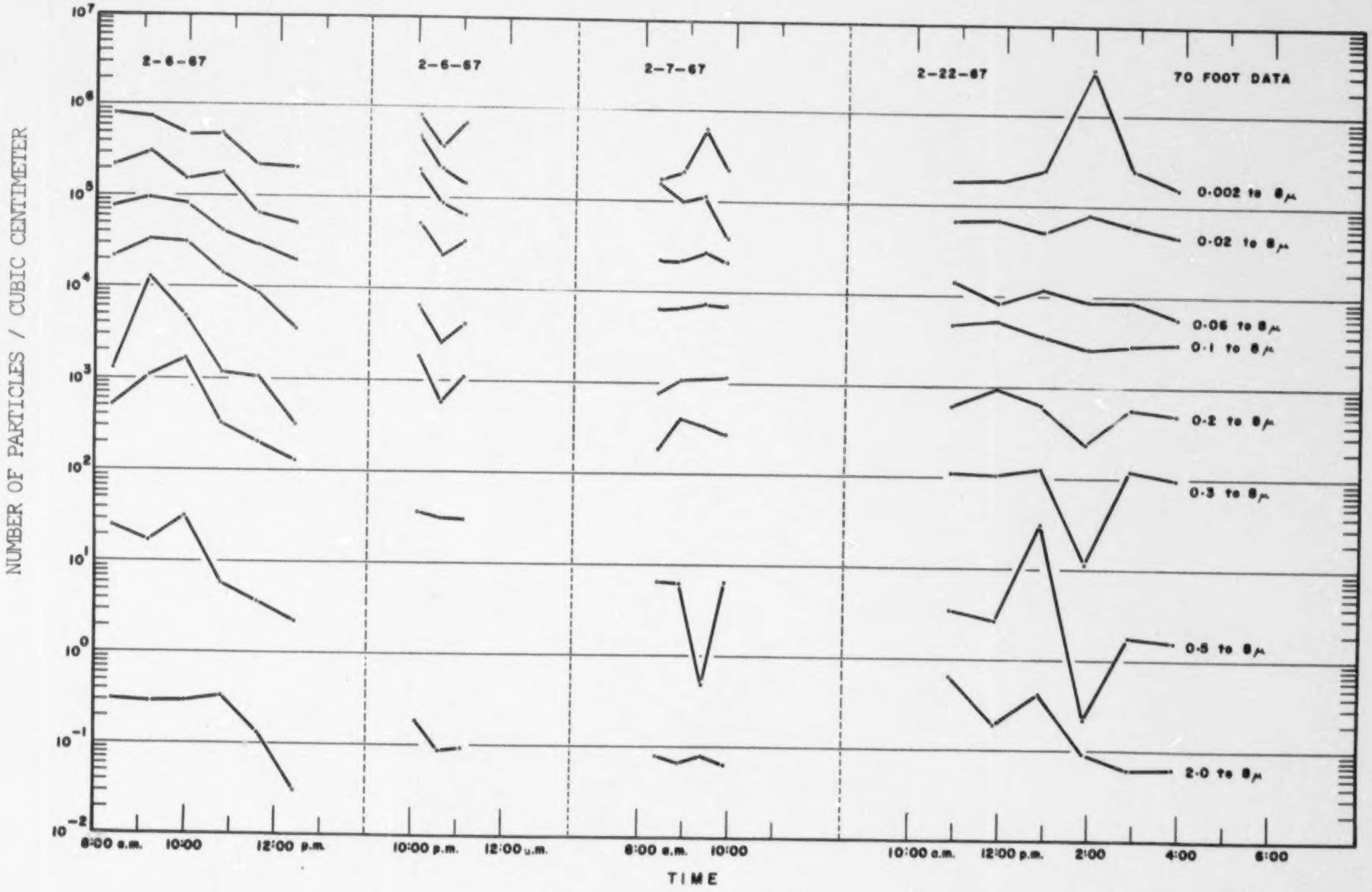


Figure 21. Plot of particle number-size values measured at the 70 foot level during the winter sampling periods.

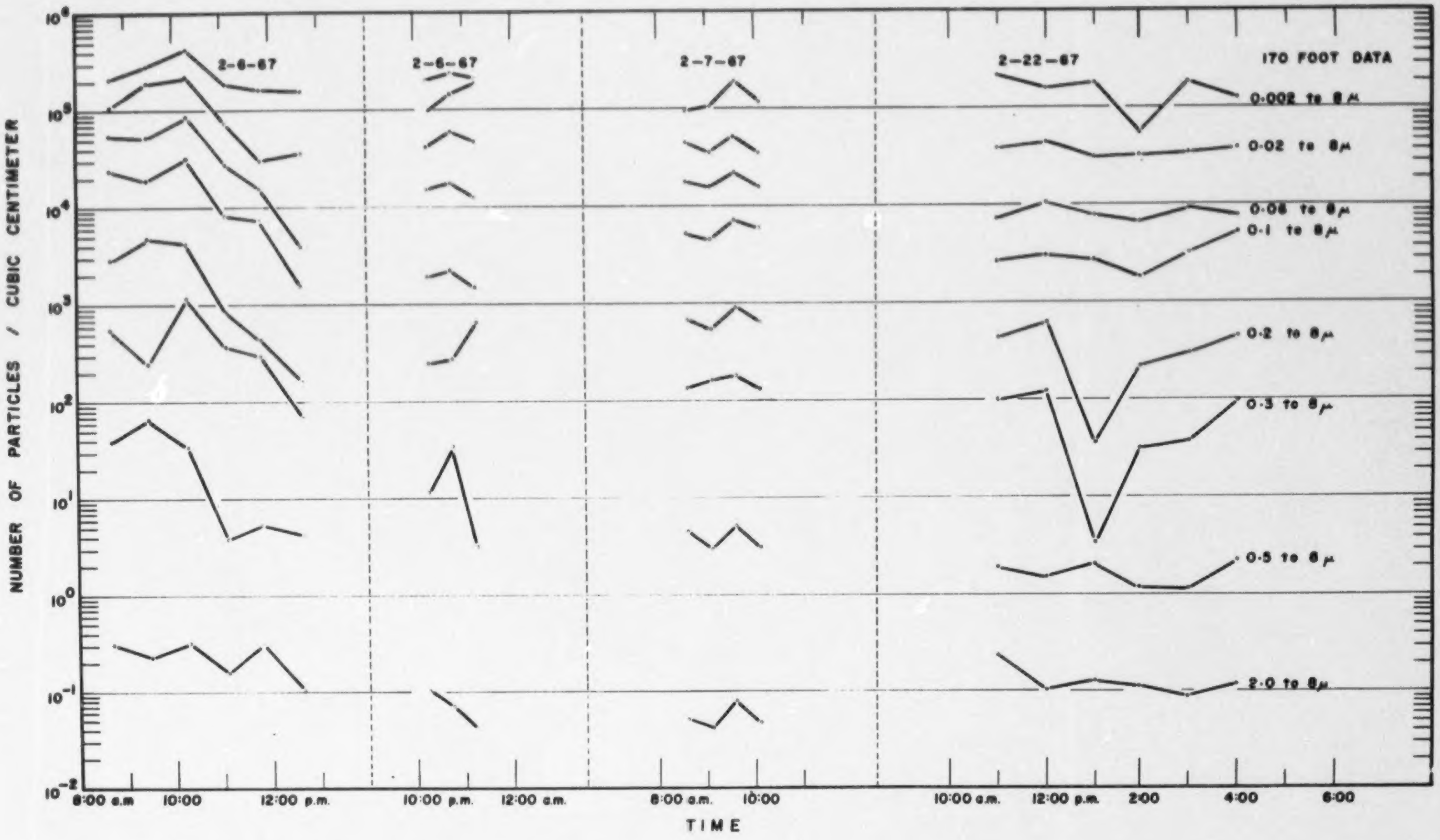


Figure 22. Plot of particle number-size values measured at the 170 foot level during the winter sampling periods.

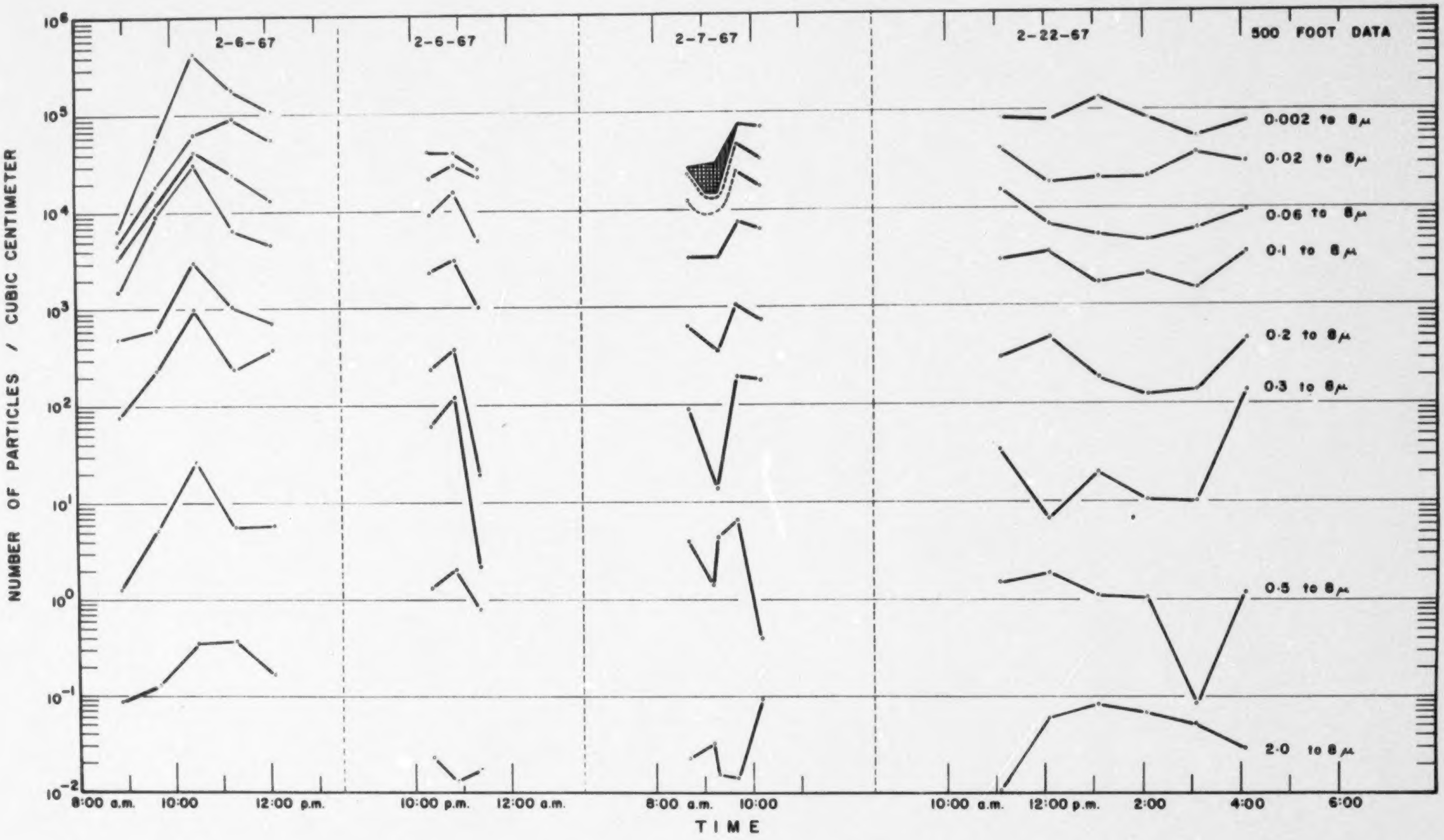


Figure 23. Plot of particle number-size values measured at the 500 foot level during the winter sampling periods.

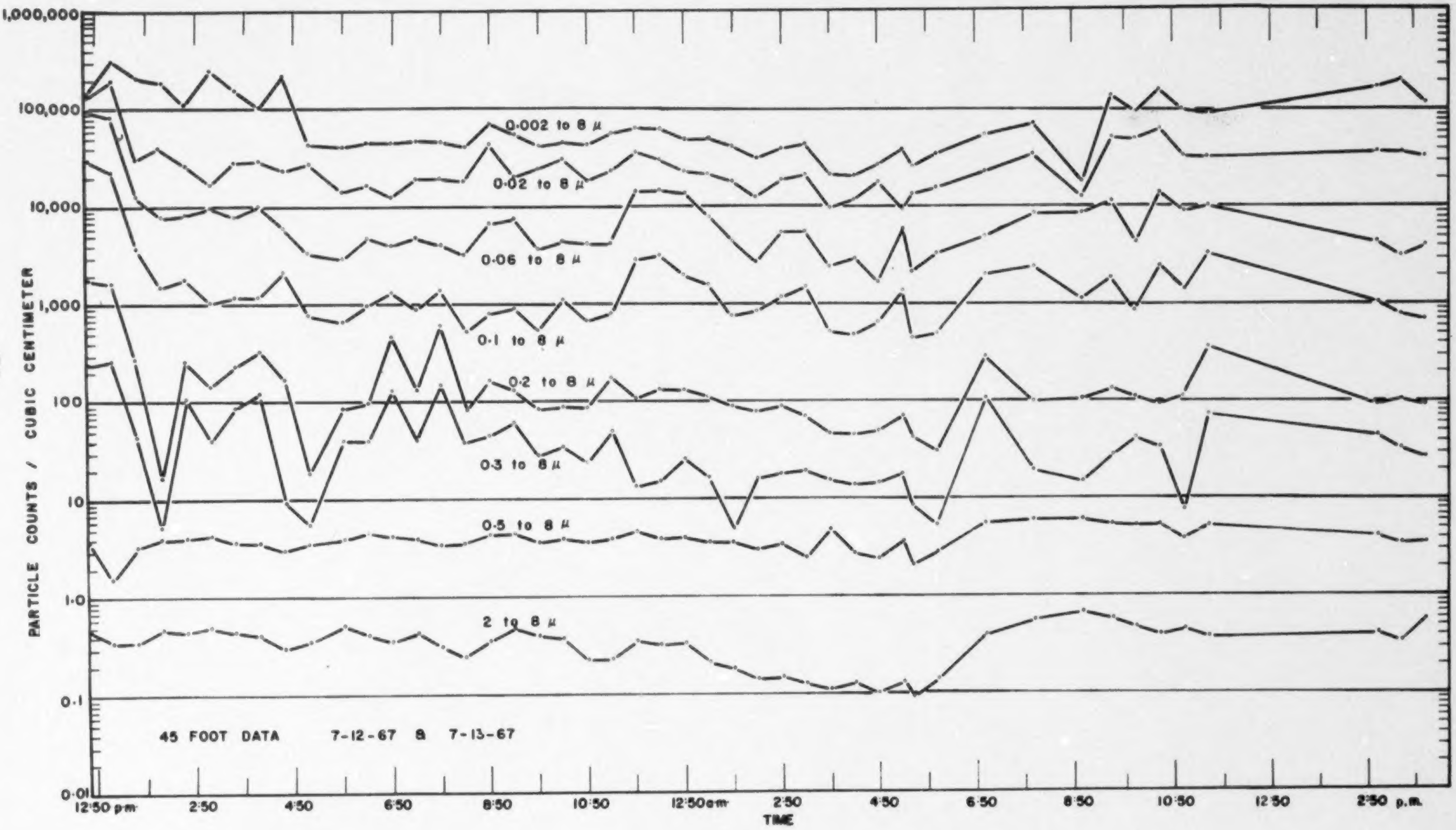


Figure 24. Plot of particle number-size values measured at the 45 foot level during the summer sampling period-12 and 13 July 1967.

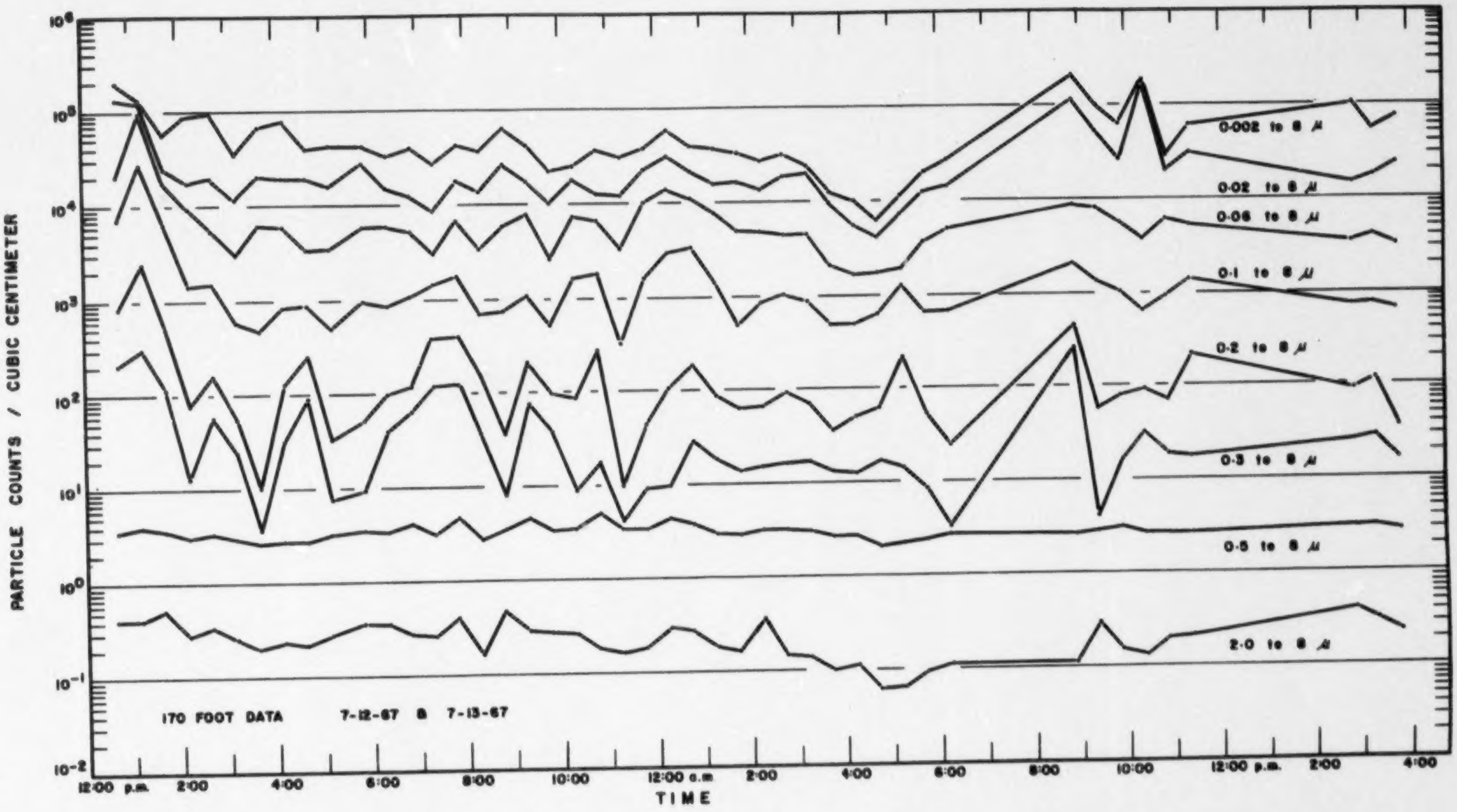


Figure 25. Plot of particle number-size values measured at the 170 foot level during the summer sampling period-12 and 13 July 1967.

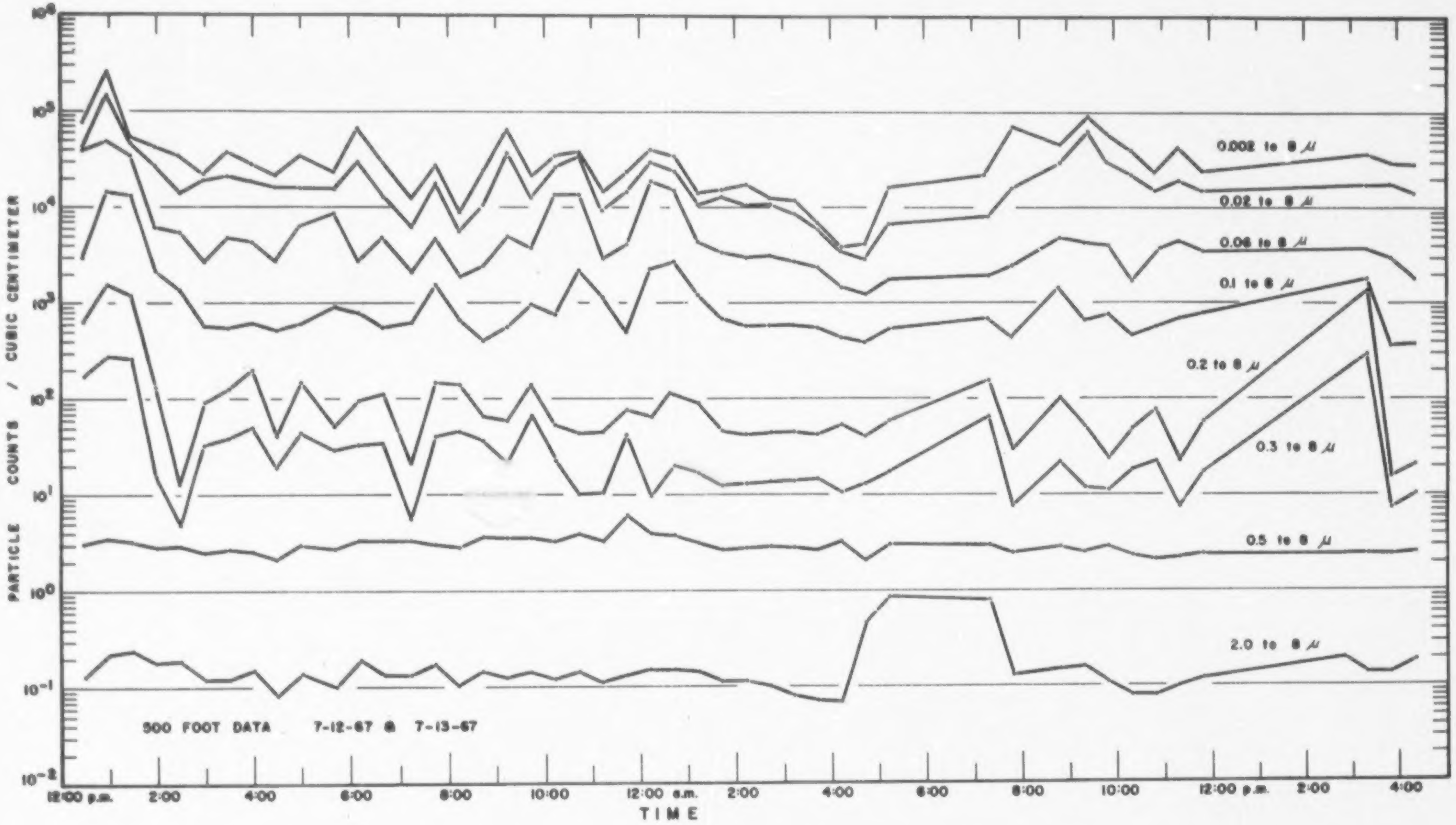


Figure 26. Plot of particle number-size values measured at the 500 foot level during the summer sampling period-12 and 13 July 1967.

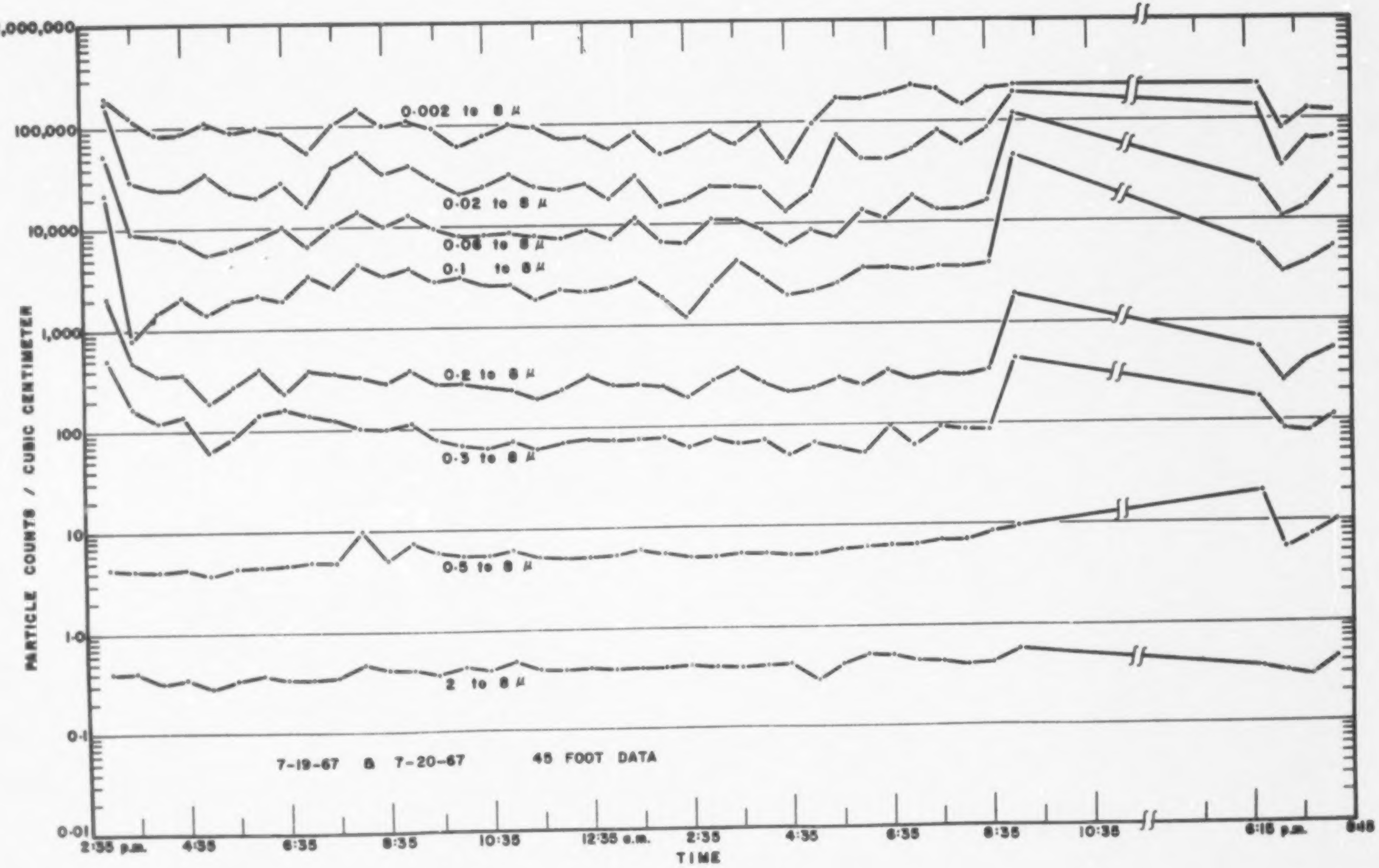


Figure 27. Plot of particle number-size values measured at the 45 foot level during the summer sampling period-19 and 20 July 1967.

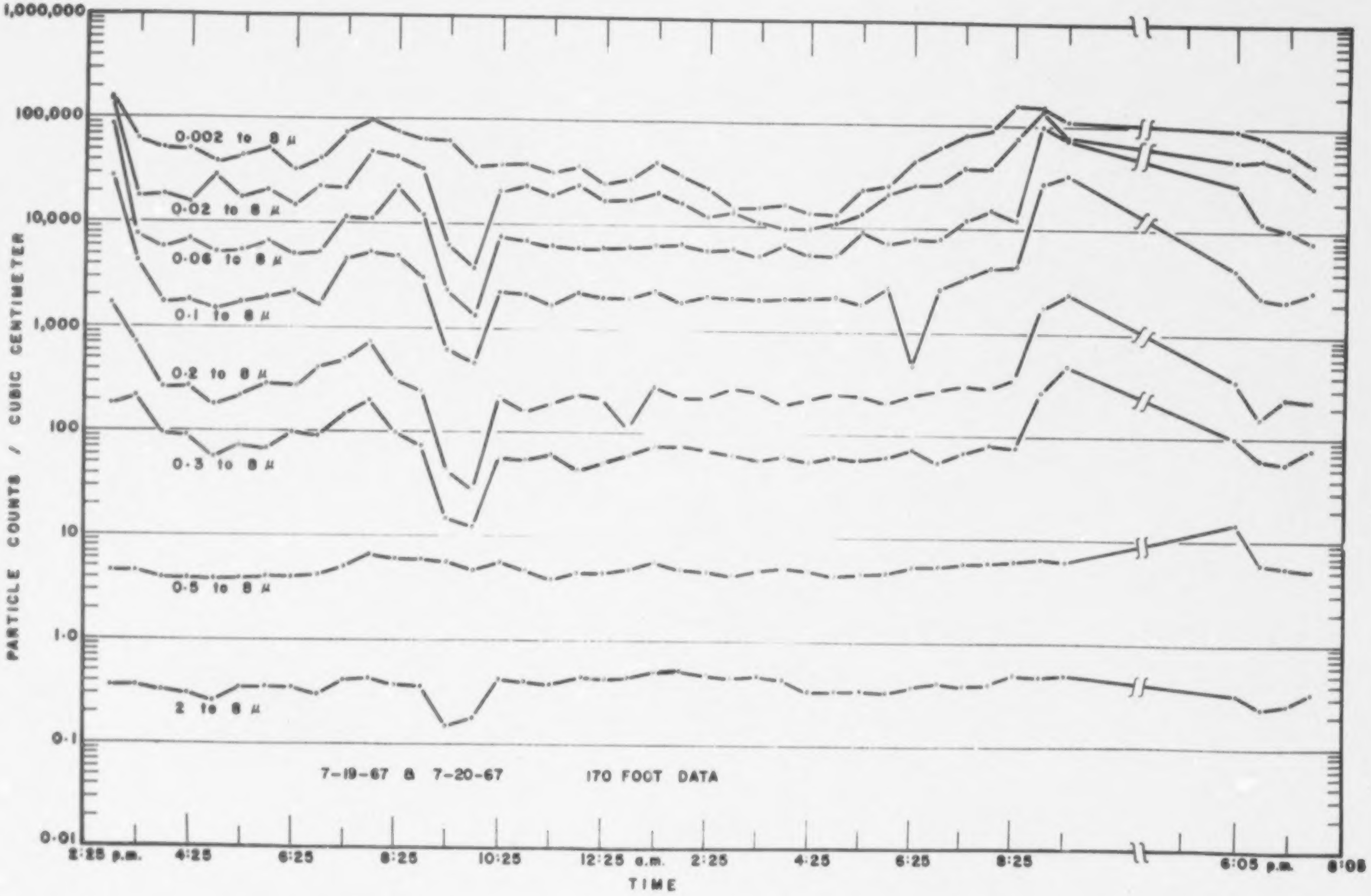


Figure 28. Plot of particle number-size values measured at the 170 foot level during the summer sampling period-19 and 20 July 1967.

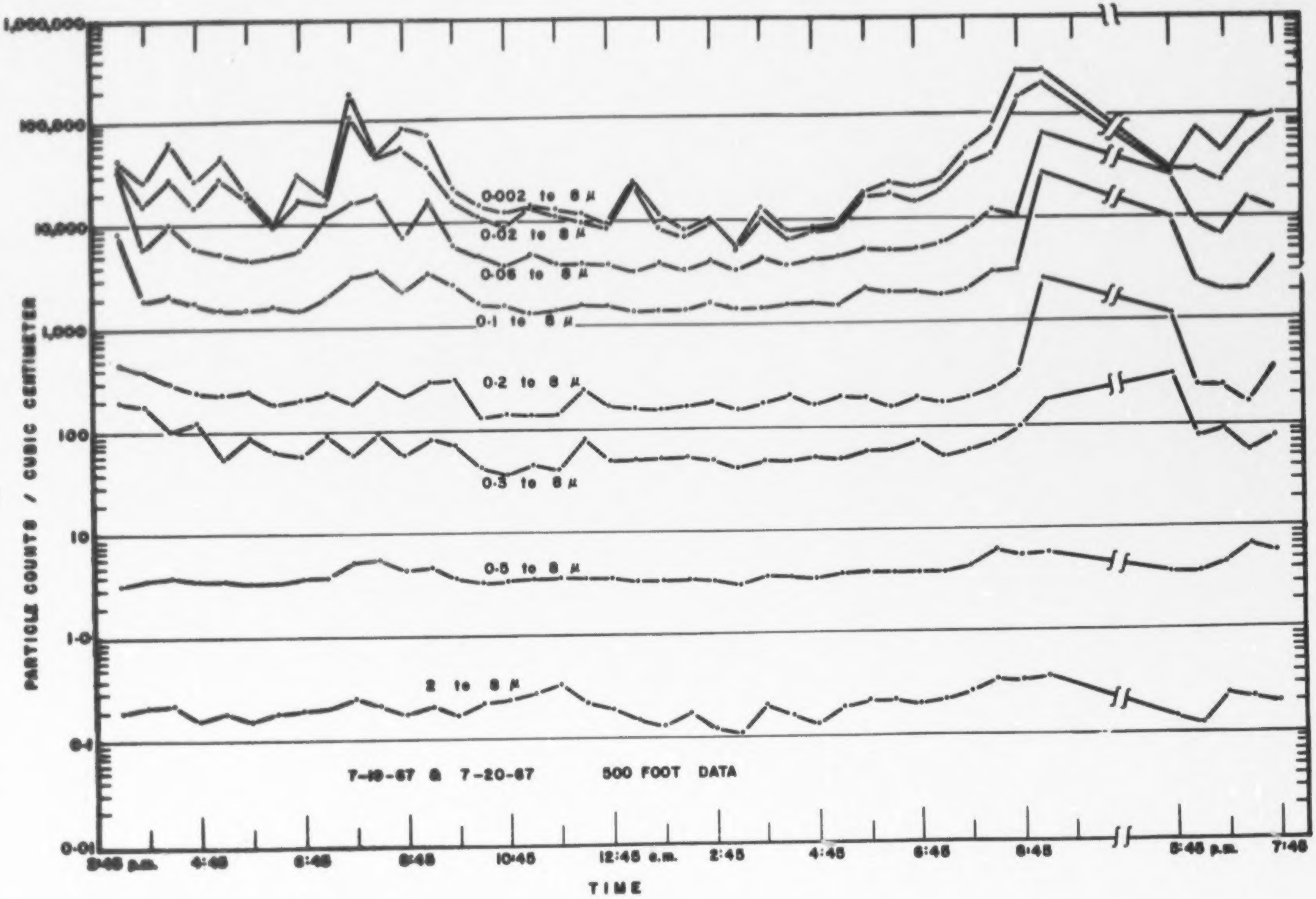


Figure 29. Plot of particle number-size values measured at the 500 foot level during the summer sampling period-19 and 20 July 1967.

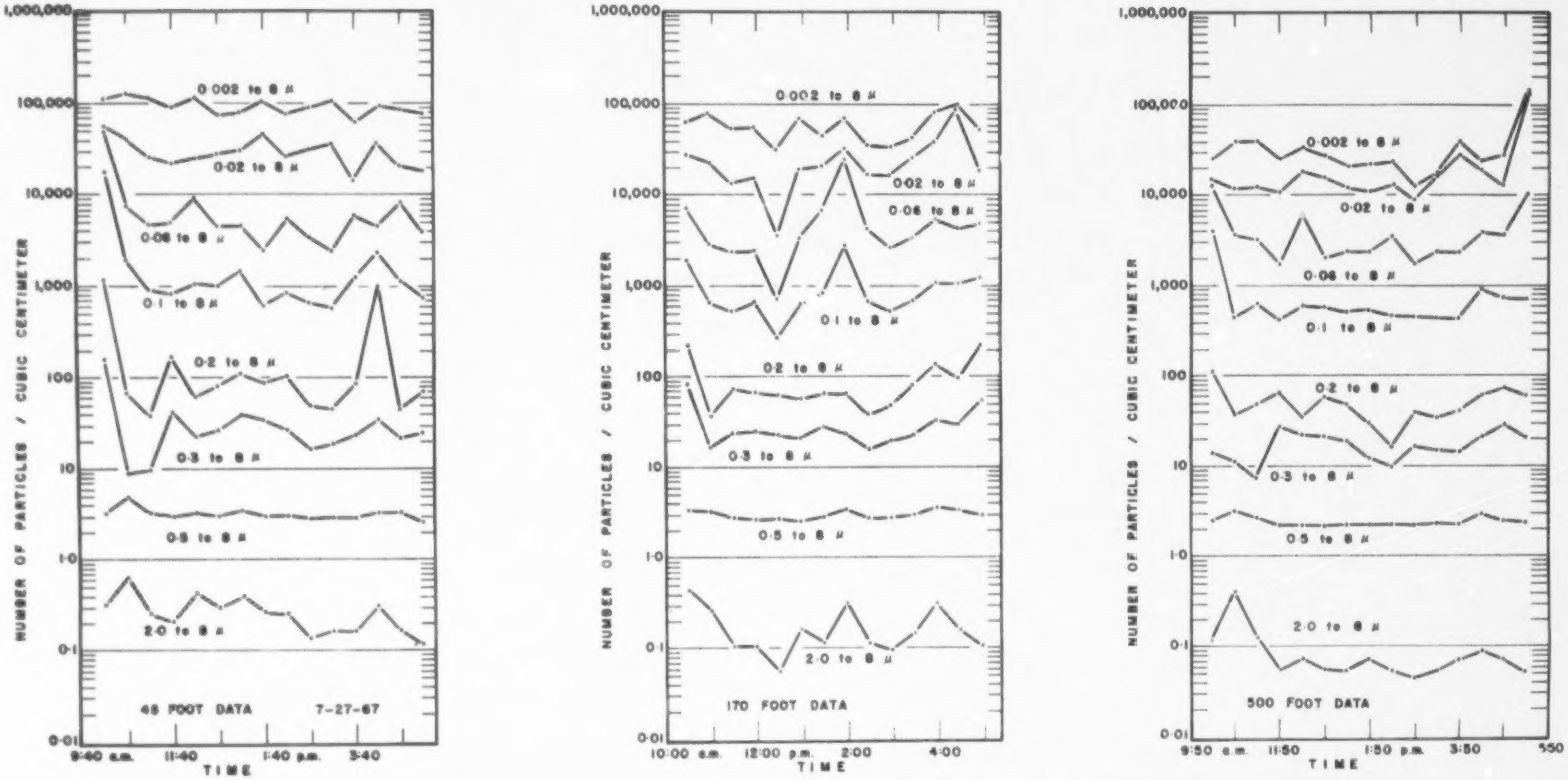


Figure 30. Plot of particle number-size values measured at the 45, 170 and 500 foot levels during the summer sampling period-27 July 1967.

lesser number of particles. Following this technique, a difference in shape between adjacent lines is attributed to the number of particles present in the size range included by the upper line and excluded by the preceeding curve. Once the difference has been generated it may continue throughout the graph or it may be modified by the addition or deletion of a number of smaller particles. Hence, if a difference were noted between the 0.2 to 8.0 micron line and the 0.3 to 8.0 micron line, the difference would be attributed to the number of particles measured within the size range from 0.2 to 0.3 micron. Variations in the width between adjacent lines is directly time related to changes in the sized particle number concentration.

C. Interpretation of Particle Data Variations With Emphasis on Meteorological Conditions

1. Particle Number-Size Characteristics and Temperature Conditions

Temperature more than any other meteorological parameter measured appeared to influence the total number of particles present in the atmosphere. The truth of this statement is seen by comparing the particle numbers for both winter and summer sampling periods. The larger number of particles in the atmosphere during the winter months is undoubtedly due to increased combustion associated with the low winter-time ambient temperature. In addition to a seasonal influence, the results of this study show that there are intraseasonal temperature and temperature distribution variations during which the number of particles present in the ambient atmosphere vary.

The effect of temperature and temperature distribution on the number of particles present and the median size of the particle number-size distribution was determined by grouping the particle data of each period according to measured temperature lapse rate at the time of particle sampling. Three distinct particle sampling categories were defined on the basis of these temperature lapse rates. Group one (1) was defined as that sampling period when the temperature lapse rate ranged from isothermal to all positive slope values (inversion conditions). Group two (2) included all sampling periods with temperature lapse rates between isothermal and adiabatic (stable air). Group three (3) was characterized as particle sampling periods performed while the temperature distribution was super adiabatic (unstable air).

From the basic particle data in each group individual and average relative number-size distribution curves were constructed and analyzed. The averaged relative number-size distributions for each distinct temperature condition are presented in Figures 31, 32, 33 and 34. Figure 31 contains the average winter sampling distributions for all three groups and for each particle sampling level. Noting that the results are presented on a log-log scale, it is readily seen that there are significant particle number-size variations with height for each group of data. In addition, there are considerable differences in the shape of the curves within each individual group. The 70 foot distributions are characteristic of modes or plateaus at distinct particle sizes. These conditions are not as evident at the 170 foot level but appear to be significant again at the 500 foot height for the group two data.

Figure 32 contains the averaged relative number-size distributions for groups 2 and 3 measured on 12 and 13 July. Modes and plateaus are absent from the average distributions plotted from the 45 foot particle data. These distributions are typical of the ones previously described in the literature. However, the curves depicting the measured particle results for the 170 and 500 foot levels have extreme peaks and valleys. The high and low particle numbers within a given number-size distribution might be explained on the basis of coagulation-sedimentation phenomenon or on upstream particle sources which emit various sized particles into the atmosphere above the 45 foot sampling height. As is common to all distribution curves there is a general decrease in relative particle numbers with each increase in height.

Figure 33 shows the average relative number-size distributions

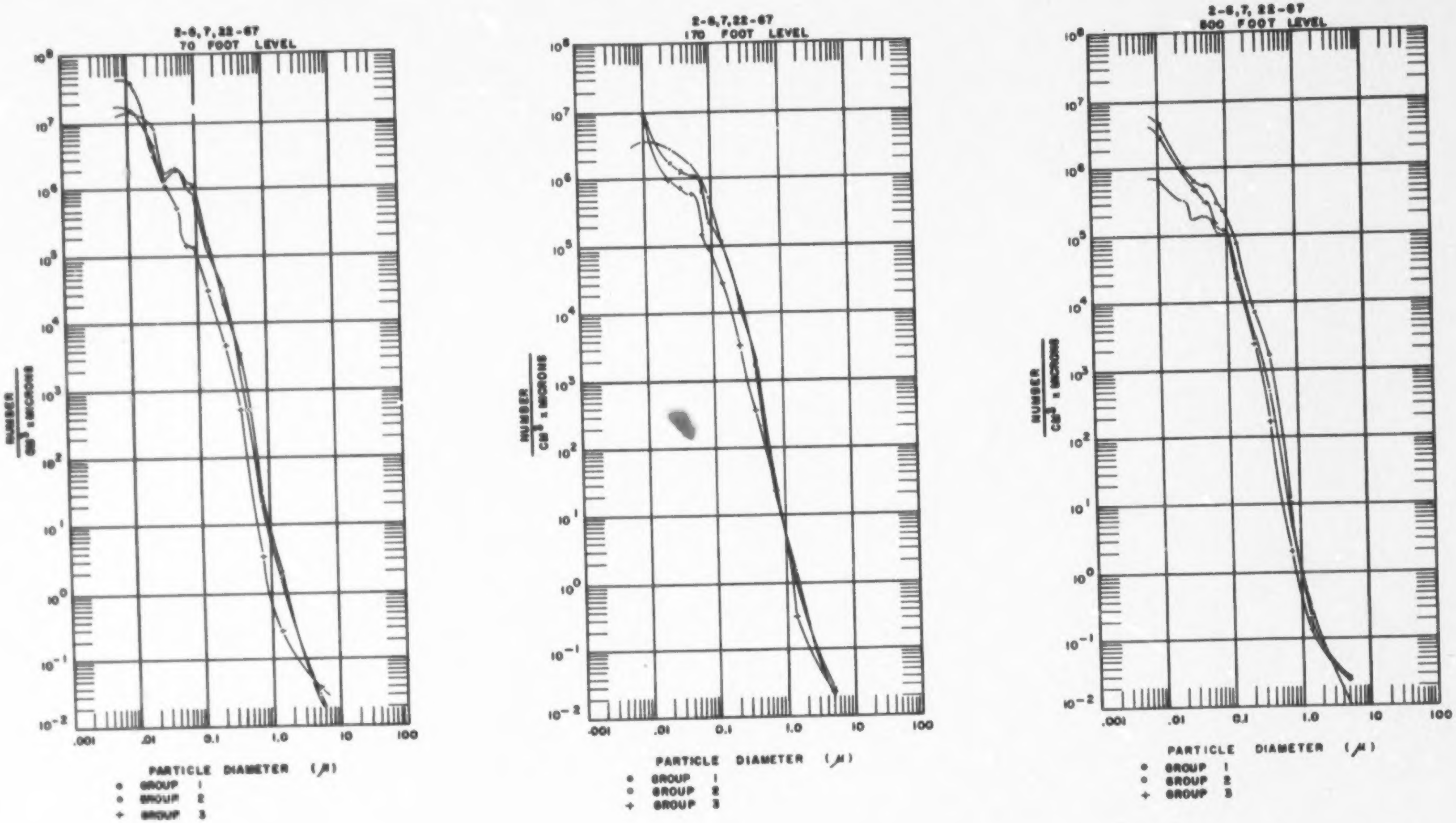


Figure 31. Average particle number-size frequency distribution curves for 6, 7 and 22 February 1967.

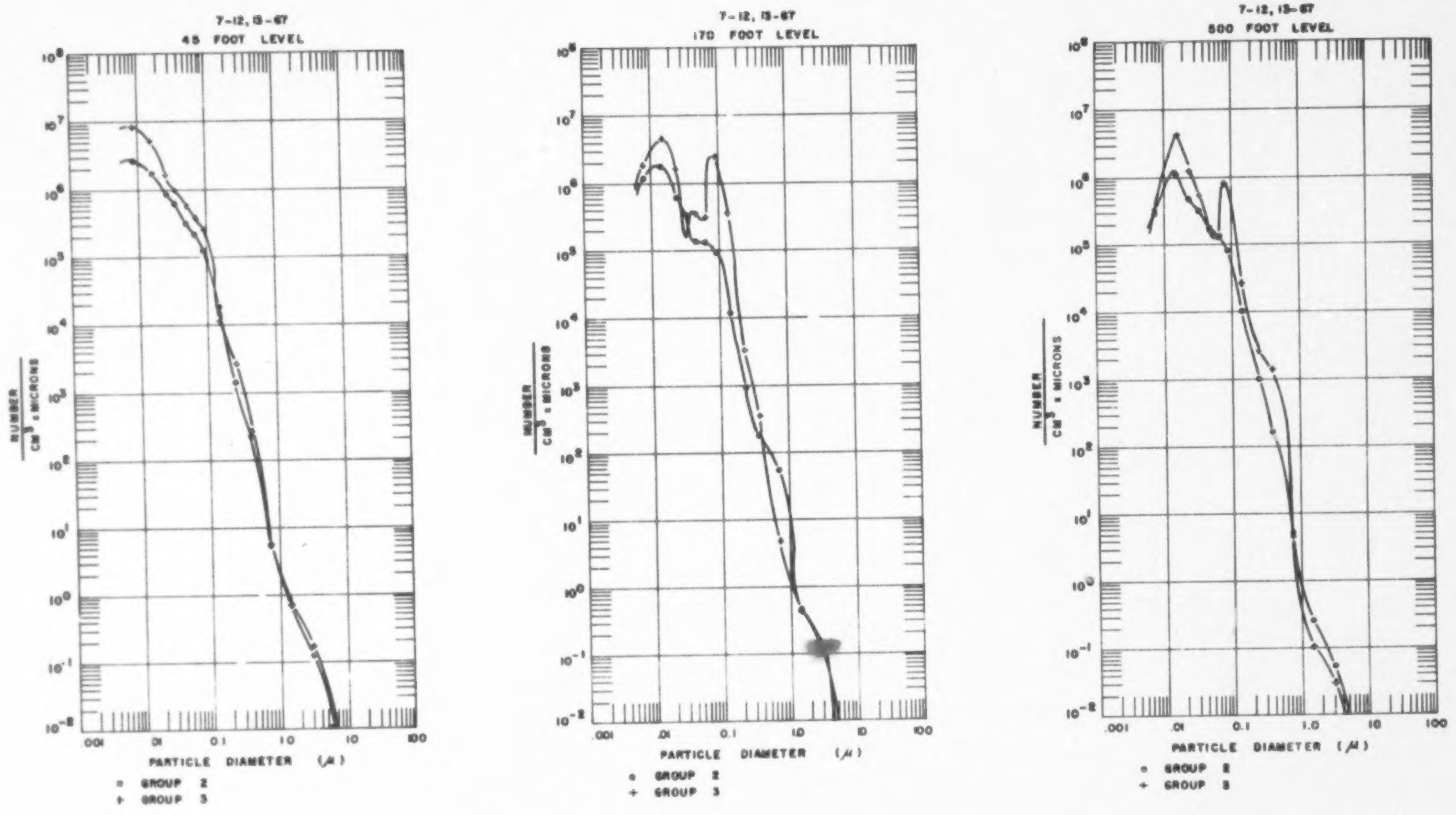


Figure 32. Average particle number-size frequency distribution curves for 12 and 13 July 1967.

calculated and plotted for groups 1, 2 and 3 measured during the sampling period of 19 and 20 July. The group 1 and 2 curves for the 45 foot level are extremely uniform but the group 3 distribution curves show considerable fluctuations with three distinct modes. Furthermore, the group 3 distribution at the 170 foot level is atypical of all the distributions measured in this study and previously reported by other investigators. The steep rise in the curve followed by a constant high relative number concentration over a log of particle sizes is very unusual. This average distribution was the result of a number of individual particle samples collected during a period when direct radiation values were high. Therefore, coagulation, sedimentation, turbulent mixing of unstable air and radiation might have been influential in producing this phenomenon. The presence of a particle source in the vicinity and upstream of the sample probe could have contributed to the final average distribution but this seems unlikely as group 1 and group 2 distributions would also have shown a similar trend. The group 2 distribution curve is significantly different at the 500 foot level. This difference is noted in both the height and shape of the curve.

Figure 34 contains group 2 and group 3 relative number-size distribution curves for the 45, 170 and 500 foot levels measured and averaged for 27 July. The curves are similarly shaped for all three levels. A decrease in relative particle number with height is generally indicated. These data were collected during an extended period of adiabatic temperature conditions. The resultant vertical mixing of air pollutants during the sampling period appears to be indicated by the uniformity in the number-size distribution curves. This is not in contradiction with the distribution curves for group 3 data presented in Figures 32 and 33. The curves in these latter Figures show considerable variation with height and fluctuations in relative number concentration at each specific height. A feasible explanation for the variations in these curves may lie in the fact that group 3 conditions did not prevail for extended periods of

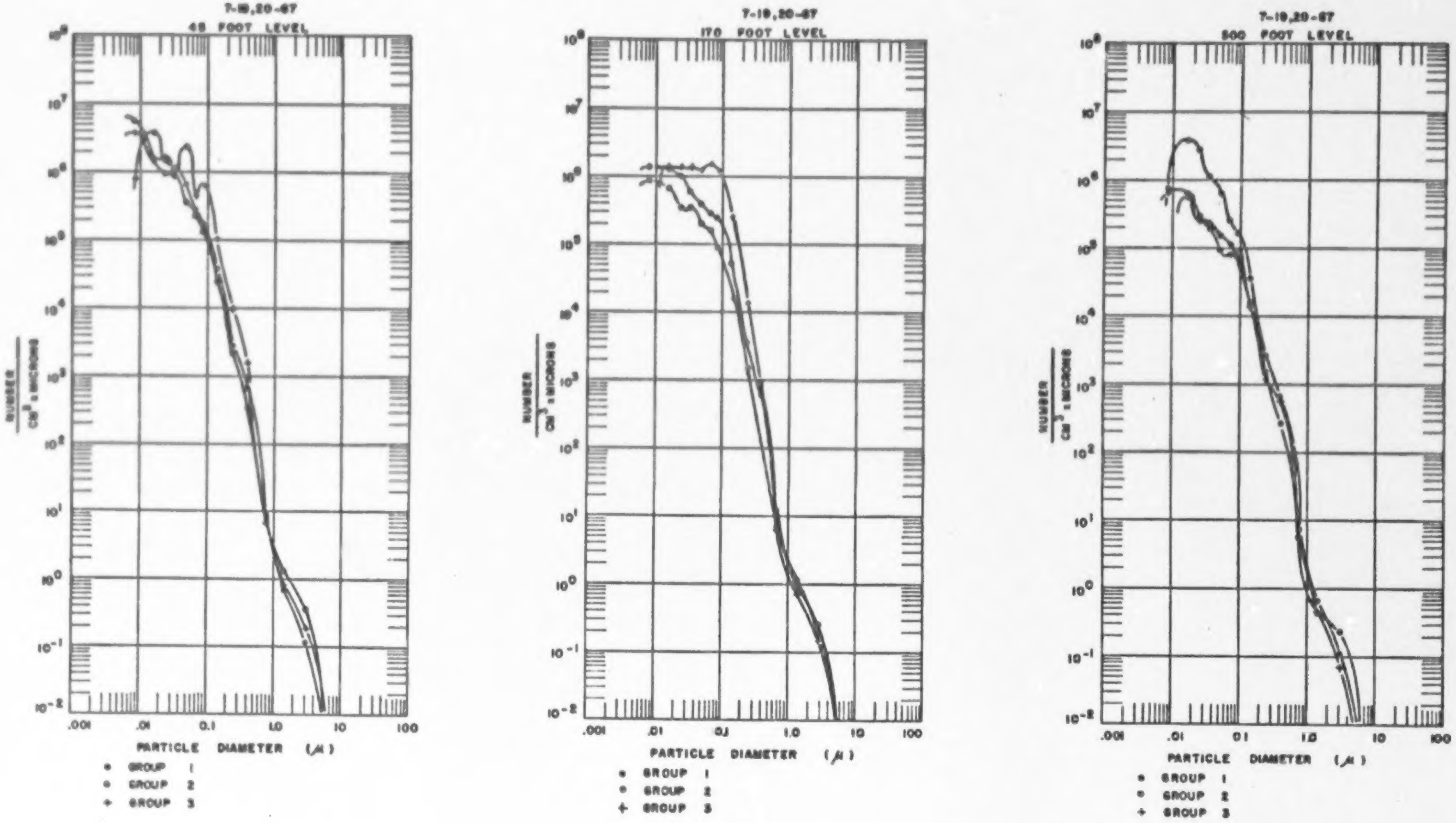


Figure 33. Average particle number-size frequency distribution curves for 19 and 20 July 1967.

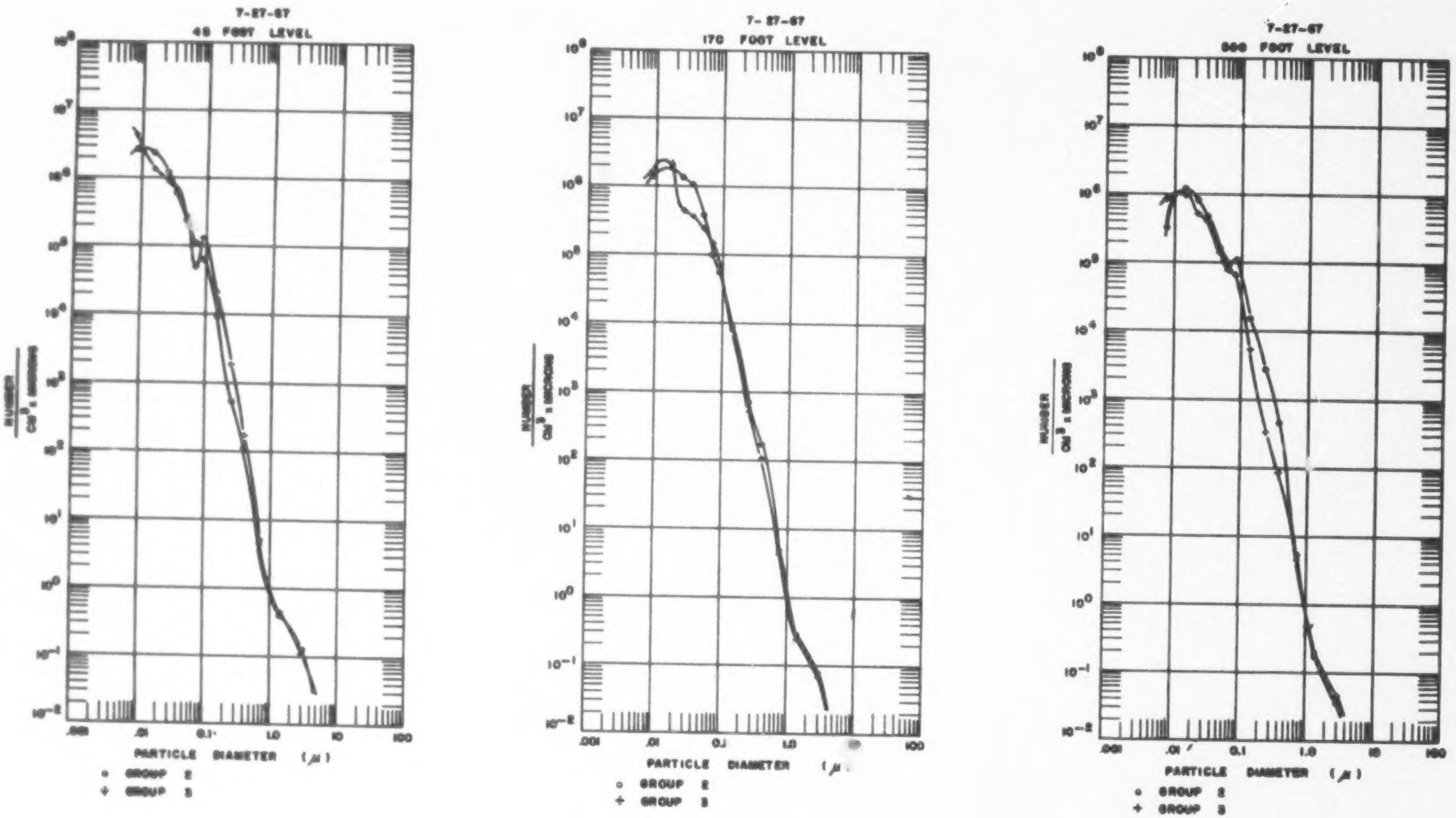


Figure 34. Average particle number-size frequency distribution curves for 27 July 1967.

time during 12, 13, 19 and 20 July. These short periods of intermittent unstable air masses may have been of sufficient length to induce particle transport to the respective levels and affect a change in the continually occurring self-preserving coagulation-sedimentation process. With the varying stable-unstable air masses the coagulation rates for various sized particles may increase due to a large influx of small particles entrained in the rising air currents during the group 3 temperature conditions. With the return to stable air conditions these rates would again equalize with the sedimentation rates and the distribution curves would show less variation during group 2 sampling periods. In theory, the effect of this phenomenon would be more pronounced at the 500-foot level. The single mode number-size distribution curve for the 500-foot level supports this hypothesis.

The average median particle size, total average particle count, average particle count greater than 0.02 micron particle size and the percentage of number-size distributions which are bi- and tri-modal are presented in Table V for each of the three temperature conditions previously described. The bimodal percentages include those curves which were also trimodal. Each array of data is presented according to winter and summer sampling periods and, in addition, the group 3 summer data are separately tabulated for the respective sampling days. Group 3 summer particle data from various sampling periods were not combined as there appeared to be significant difference in data depending on whether it was accumulated during extended periods of unstable air conditions or during short intervals of unstable air interphased with predominantly stable air conditions.

With the particle data averaged according to inversion, stable and unstable air it is seen, in Table V, that the average median particle size varies with height most significantly during inversion conditions. For winter sampling periods, the average median particle size at the 70-foot level was found to be nearly constant for all groups. The average median particle size decreases in

Winter Sampling Temperature Distributions

	Inversion				Stable				Unstable			
Height Measured (feet)	70	170	500	a	70	170	500	b	70	170	500	c
Ave. Median Part. Size(micron)	0.018	0.027	0.043		0.018	0.02	0.026		0.015	0.015	0.018	
Total Ave. Part. Counts(No./cm^3)	485,702	178,653	28,422		487,284	205,904	133,687		746,784	152,328	80,650	
Total Ave. Part. Counts for Part. Greater than 0.02 Micron(No./cm^3)	195,901	112,413	17,028		172,284	84,764	48,727		64,584	37,127	26,910	
Bimodal Dist. (%)	80	60	60		100	86	71		16.6	16.6	11.1	
Trimodal Dist. (%)	40	40	0		1.4	0	1.4		0	0	0	

Summer Sampling Temperature Distributions

	Inversion				Stable				Unstable			
Height Measured (feet)	45	170	500		45	170	500	d	45	170	500	e
Ave. Median Part. Size(micron)					0.031	0.033	0.043		0.022	0.033	0.037	
Total Ave. Part. Counts(No./cm^3)					67,883	44,773	27,867		185,602	90,568	59,934	
Total Ave. Part. Counts for Part. Greater than 0.02 Micron(No./cm^3)					22,452	21,463	17,801		53,572	42,588	52,920	
Bimodal Dist. (%)					80	76	59		80	60	70	
Trimodal Dist. (%)					15	21	0.7		0	0	0	
Height Measured (feet)	45	170	500	f	45	170	500	g	45	170	500	h
Ave. Median Part. Size(micron)	0.026	0.045	0.065		0.029	0.038	0.048		0.021	0.026	0.03	
Total Ave. Part. Counts(No./cm^3)	106,942	36,171	16,244		114,385	74,868	79,909		135,640	52,035	32,035	
Total Ave. Part. Counts for Part. Greater than 0.02 Micron(No./cm^3)	34,992	19,882	13,399		58,385	47,048	50,137		70,540	18,705	15,726	
Bimodal Dist. (%)	86	82	91		74	75	75		79	71	57	
Trimodal Dist. (%)	19	50	24		21	35	20		29	29	21	

2/6-7/67 sampling period - a,b
7/12-13/67 sampling period - d,e
7/27/67 sampling period - h

2/22/67 sampling period - c
7/19-20/67 sampling period - f,g

Table V. Average particle distribution values for three temperature conditions.

magnitude at the other two levels as the air masses become less stable. Therefore, the largest average median particle size was measured at the 500-foot level during periods of temperature inversion. A decrease in median particle size at the 170 and 500 foot levels with the formation of unstable air resulted in nearly identical average median particle sizes at all three levels when super-adiabatic conditions existed. Median particle sizes calculated for summer sampling periods were larger in magnitude but showed the same general trend in regard to the decrease in size in the order of inversion, stable and unstable conditions. The uniformity in median particle size with height for the group 3 data is not as pronounced during the summer sampling period compared to the winter period. This could be due to the varied sources capable of emitting uniquely-sized particles and the lack of the common combustion sources which are predominant during the winter months.

The particle counts of the inversion group recorded during winter and summer sampling show similar trends. However, the number magnitude is definitely greater during the winter months. In both cases high particle number counts are recorded at the lowest sampling level and this is followed by a decrease in magnitude with height. This is the general trend noted for all sampling periods but it is more pronounced during inversion conditions. From the count of particles greater than 0.02 micron, it is seen that the percentage of small particles (less than 0.02 micron) at the 70 or 45 foot level far exceeds that detected at the 170 and 500 foot levels. This phenomenon appears to be a function of the inversion strength and is related to the amount of air turbulence. During periods of stable air conditions, coagulation times are increased and this may also be a factor in the number of small particles measured at the upper levels. An inversion is characteristically a stable air condition and air below the base of the inversion is confined to that volume throughout the duration of the inversion. Furthermore, the general absence of turbulence reduces the amount of mixing within the confined volume. The mass of air within the positive lapse rate region is also stable and if this layer is at the approximate height of a number of sources of pollution the pollutants emitted in the layer will remain in the layer. Consequently, coagulation and sedimentation are the major processes which are free to affect the particles confined to the inversion layer. Coagulation proceeds to form large particles from smaller ones and the larger particles are removed from the volume by sedimentation. As this process continues the number of small particles decreases and the mean particle size increases.

The values for the stable air conditions may be somewhat biased as a major portion of the individual sample results are representative of sampling periods following or preceeding group 1 conditions. An exception to this rule is the group 2 data averaged for the 12 and 13 July. It is interesting to note that the average results of this period are similar to those obtained during the other possibly biased group 2 sampling periods. The tabulated average data of group 2 appears to show the effect of increased air mixing. The number of particles in the lower levels have not significantly decreased but the difference in magnitude between the lower and upper levels is definitely less. This is due to an increase in particles at the upper levels. The increase is noted in all size increments but to a greater extent in the smaller particle size ranges. This results in a decrease in the average mean particle size at the elevated levels and the overall uniformity in the particle samples collected from each height.

The effect of increased air mixing is further reflected in the particle number data established for the group 3 periods. In general, the particle number difference between particles counted at each sample level continues to decrease in magnitude from that experienced for the inversion condition. The tabulation of number of particles greater than 0.02 micron shows more conformity to this generally established pattern than do the total particle counts. In fact, due to the tremendous increase in the number of small particles present in the unstable air samples the overall total particles counted for group 3 exceeds the counts of the other two groups. This notable increase in small particles at all levels leads to an interesting phenomenon which appears to exist during all measured super adiabatic monitoring periods. The presence of these small particles is presently explained on the basis of rising unstable air masses, particle concentrations not previously measured, increased turbulence and coagulation.

The physics and mathematics of rising air masses are complex but it is generally accepted that unstable air masses will rise in height until they reach a level in which they are stable with the surrounding environment. The rate of ascent is dependent on the instability of the air masses which is reflected in the measured temperature lapse rate. It is natural to assume that as air masses rise they carry or force airborne particulates upward and the smaller the particle the more pronounced the effect. Since the concentration of airborne particles below the 45 foot level was never measured there is a possibility that this region contains an extremely high number of small particles. With increased vertical air movement these small particles would be lifted or buoyed upward to a height where they are exposed to turbulent air streams. Turbulence would tend to disperse these particles and in effect the chance of small particle coagulation would be reduced. Coagulation would not be elminated but if the initial particle emission to the atmosphere is followed by a rapid upward motion the effect of coagulation would be reduced and the reduction would be reflected in the detection of a large number of small particles at each sampling height.

The percentage of individual relative number-size distribution curves which were bi- and tri-modal are included as part of the tabulated data in Table V. Prior to this study it was generally assumed that all relative number-size distribution curves should gradually increase to a peak value and subsequently decrease in magnitude. This assumption was initiated by Junge (23) wherein he summarized the results of his measurements with the following comments:

> "The available data seem to indicate that the maximum number concentration is located in the size region between 10^{-5} and 10^{-6} on radius, and that the number concentration drops to zero between $10^{-6}$and 10^{-7}on radius. The size range greater than 10^{-5} cm can be well represented by a power law which seems to hold for large parts of the world." (23)

The high percentage of bi- and tri-modal curves established from the analysis of data is definitely in conflict with the earlier statement by Junge. However, his comments were made on the basis of particle data derived from sampling techniques not capable of accurately sampling or sensing particles smaller than approximately 0.05 micron diameter and in addition his results were time averaged. In essence Junge was not sampling within the size range of particles where some of the most dominant peaks or modes are noted and time averaging sampling procedures reduces the probability of detecting unique modes within the distribution curves.

The percentage values established for each group and for each sampling period indicates that the number-size distribution curves during inversion conditions are most variant. Furthermore, the distributions measured during the summer are more variant in nature than those measured during the winter periods. The latter variations may be attributed to the lack of combustion sources during the summer or insufficient particle numbers to create a uniformly aged aerosol.

Averaging individual particle number-size measurements and analyzing the resultant average values is basic to the interpretation of large volumes of data such as presented in this study. The major shortcoming of this investigative technique is that certain particle behavior patterns unique to specific meteorological conditons may not be detected in the averaged results. A review of the individual relative number-size distributions which were later averaged to obtain the average group data showed a much more significant change in particle number-size data than noted by reviewing the averaged results. This is particularly true of group 1 data. Examination of specific particle number-size distributions during inversion conditions revealed extreme variations in the relative number of particles measured at the respective sampling heights. This phenomenon occurred when the inversion was at or near maximum stability and as the inversion weakened the measured distribution changed. A larger number of distributions measured during inversion formation or after full strength and averaged with the maximum stability period tends to generalize and de-emphasize the conditions prevalent at the time of maximum inversion strength. Figure 35 is presented to show the extreme variation in particle number which occurred during group 1 conditions of 6 February 1967. In essence the Figure shows the number-size distributions for each level during the period when the inversion was near maximum stability and the number-size distribution measured after the inversion had dissipated. The uniformity in the individual number-size distribution curves measured during a super adiabatic temperature period of 22 February 1967 is shown in Figure 36.

2. Particle Number Measurements, Direct Radiation and Wind Speed

It was previously noted that some of the more significant variations in particle number concentrations occurred in the size range from 0.1 to 0.5 micron. It is also noted that a number of these variations coincide with high and low direct radiation measurements and it is proposed that the amount of radiant energy is a factor in the variation in the number-size distributions. The occurrence of this phenomenon is particularly pronounced during the sampling period of 12 and 13 July. A graphical presentation of the direct radiation values for this period is shown in Figure 17. The particle number variations per size range are graphically presented for the 45, 170 and 500 foot levels respectively in Figures 24, 25 and 26. It is noted that with each significant decrease in measured direct radiation there is a corresponding decrease in particle counts. The latter decrease is most pronounced within the 0.2 to 0.5 micron particle size range.

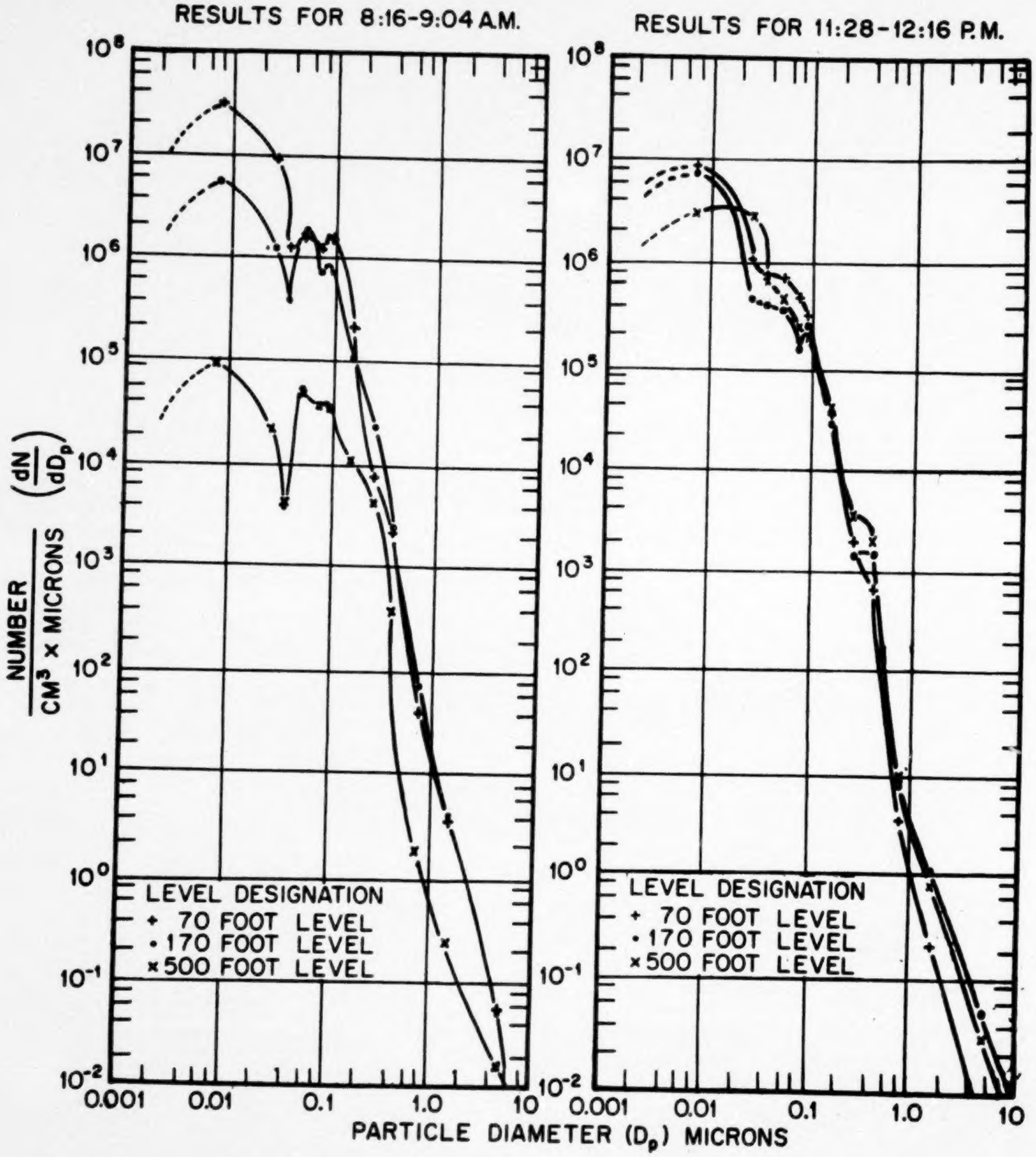


Figure 35. Time specific particle number-size frequency distribution curves measured during and after an inversion.

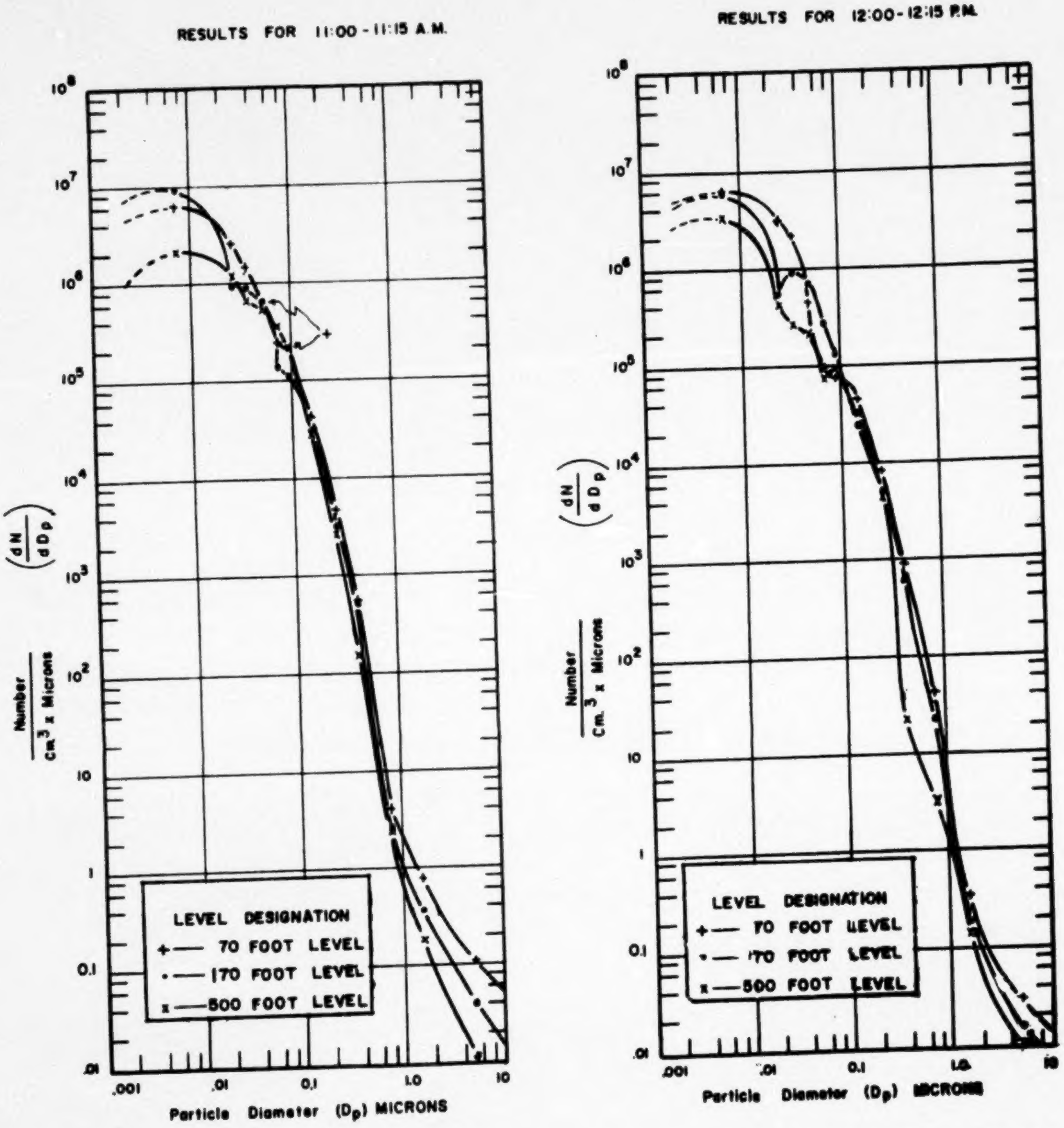


Figure 36. Time specific particle number-size frequency distribution curves measured during a period of unstable air.

The particle number response to direct radiation changes is particularly evident during the sampling period from 1400 to 1800 hours on 12 July and beginning at sunrise and extending to 1000 hours on 13 July. Particle number variations do occur during the absence of sunlight or direct radiation but for most sampling periods the variations are more significant during the daylight hours. In addition, particle number variations gradually decrease in magnitude as nocturnal sampling proceeds from sunset to sunrise. With these conditions prevailing, it is logical to assume that the variations are due to a number of factors including direct radiation. The prime factor may be automobile emissions for the generally expected decrease in traffic flow and the nocturnal decrease in particle numbers occur during the same time period. Additionally, it is known that gas engine emissions are composed of a high number of particles of which a large percentage contain unburned hydrocarbons. Hydrocarbons are known to react when exposed to direct radiation. The total reaction in the environment has not been fully investigated but it is possible that increased irradiation of large particles could result in the production of a number of small particles within specific size ranges. Additional laboratory and environmental test data are needed in this area of hypothesis.

Particle number-size data were reviewed to determine whether wind speed was instrumental in affecting atmospheric particle behavior. The review was based on the 70 foot level wind speed. Particle data collected during periods when the wind speed was less than 9 knots/hour was compared to data acquired when the wind speed was greater than 9 knots. The effect of wind speed on the particle number-size distribution or total concentration was not definitively defined. However, particle number variations which were reviewed on the basis of temperature or radiation could possibly have been enhanced or tempered by the specific wind speeds measured. A study of the synergistic action between wind speed and other parameters will require additional meteorological and particle data so that correlation and significance test values may accurately be determined.

D. Conformance of Measured Particle Data to Proposed Self-Preserving Size Distributions

Most atmospheric aerosol studies conducted prior to this investigation were generally concerned only with the determination of a single particle number-size distribution and the resultant conformance to the self-preserving size distribution theory. The significance, the physical and the mathematical justification for and some previously reported results in support of the self-preserving size distribution theory are discussed in Chapter II. Due to the strong similarity in shape of most measured distributions the self-preserving size distribution theory initially proposed by Junge (23) has been widely accepted. Friedlander (25, 26) and Liu and Whitby (33) have contributed significantly to the substantiation, interpretation and importance of the self-preserving theory. As reviewed in Chapter II, Friedlander (25) initially proposed that the similarities in size distributions can be explained by the existence of certain special solutions to equations which describe the rate of change of particle size distribution with time. These equations appropriately describe the rate of change of the particle number-size distribution with time and account for the decay processes of coagulation and sedimentation but the final expression was a partial integro-differential equation which can not be solved without first establishing the initial and boundary conditions. These conditions cannot be specified for the urban atmosphere and Friedlander (26) later showed that through similarity transformations the number of independent variables may be reduced and the self-preserving form of the size distribution can be given by equation 14.

$$n(r) = (N_t^{4/3} / \phi^{1/3}) \, \Psi \, [r(N_t / \phi)^{1/3}] = (N_t^{4/3} / \phi^{1/3}) \, \Psi \, (\eta) \tag{14}$$

Where:

$n(r)$ = derivative of particle number with respect to particle size

N_t = total number of particles counted, number per cm^3

r = particle radius, micron

ϕ = total particulate volume per unit volume of aerosol, $micron^3$ per cm^3

Ψ = dimensionless size distribution function dependent only upon

$$r = r(N_t / \phi)^{1/3}$$

η = independent dimensionless parameter

Swift and Friedlander (31) have shown that equation 14 is a solution to the equation describing the kinetic decay process of coagulation by Brownian Motion. Therefore, when measured particle numbers within specific size increments are used in the calculation of the dimensionless parameter, Ψ and η, and the results are plotted on dimensionless coordinates the values will fall on a single curve if the original data were either approaching or had established a self-preserving form. In addition, Liu and Whitby (33) have shown that if the existence of a self-preserving solution to the kinetic equation is assumed and the aerosol is in a state of dynamic equilibrium then it follows as a consequence that the size distribution function, $n(r)$, is proportional to r^{-4}. The significance of this statement is that when Ψ is plotted as a function of η and it is established that Ψ is proportional to η^{-4} then the aerosol is in a state of dynamic equilibruim. With the state of dynamic equilibruim confirmed over a range of the particle size spectrum it can be assumed that the rate of gain of particles in the sub-range due to coagulation of particles is equal to the rate of loss of particles due to sedimentation.

A limited amount of experimental data has been available to substantiate the theory by Friedlander or investigate whether the state of dynamic equilibruim is actually achieved within the aero-environment. Basically, the data available prior to this study did not meet the time dependent measurement requirements upon which the theories were developed. The best previous data had been collected once every hour. In this study, particle number-size distributions were established every ten minutes and hence are more sensitive to the time dependent changes. The Ψ and η values for 360 independent number-size distributions were calculated and plotted on log-log coordinates. The distributions were made up of an equal number of measurements taken from each of the three sample levels. The plots of Ψ versus η are shown in Figures 37, 38 and 39 for the respective 45, 170 and 500 foot sample heights.

The solid line drawn on each Figure was constructed on the basis of the least square difference of each plotted point and was established by using all data values for particle sizes greater than 0.1 micron diameter. The values for Ψ representing a particle size of 0.1 micron are located on each figure in the approximate region of η equal 1.0. It is seen that Ψ and η plotted for particle sizes greater than 0.1 micron consistently fall on a straight line pattern. As previously stated it is the slope of this line which determines the self-preserving form of the distribution. With a slope of -4 the distribution is in a state of dynamic equilibruim. A dashed line drawn with a slope of -4 is shown on each Figure. The slope of the solid line determined for the 45, 170 and 500 foot levels were respectively -3.6, -3.7 and -3.98. These results and the theoretical interpretation by Liu and Whitby (33) show that the state of dynamic equilibruim is approached as the aerosol mixture rises in the atmosphere. Furthermore, it also shows that equilibruim is essentially reached at the 500 foot level.

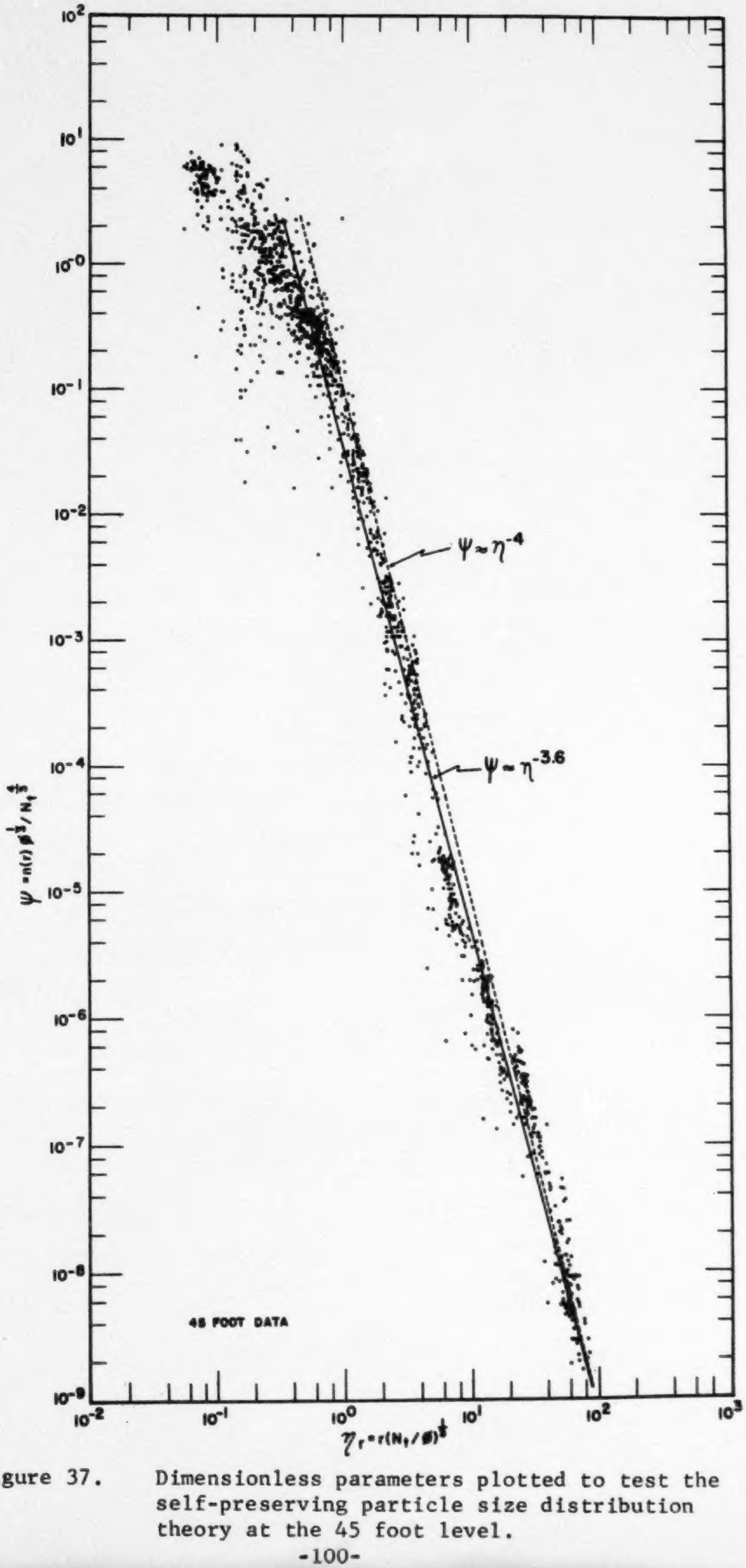


Figure 37. Dimensionless parameters plotted to test the self-preserving particle size distribution theory at the 45 foot level.

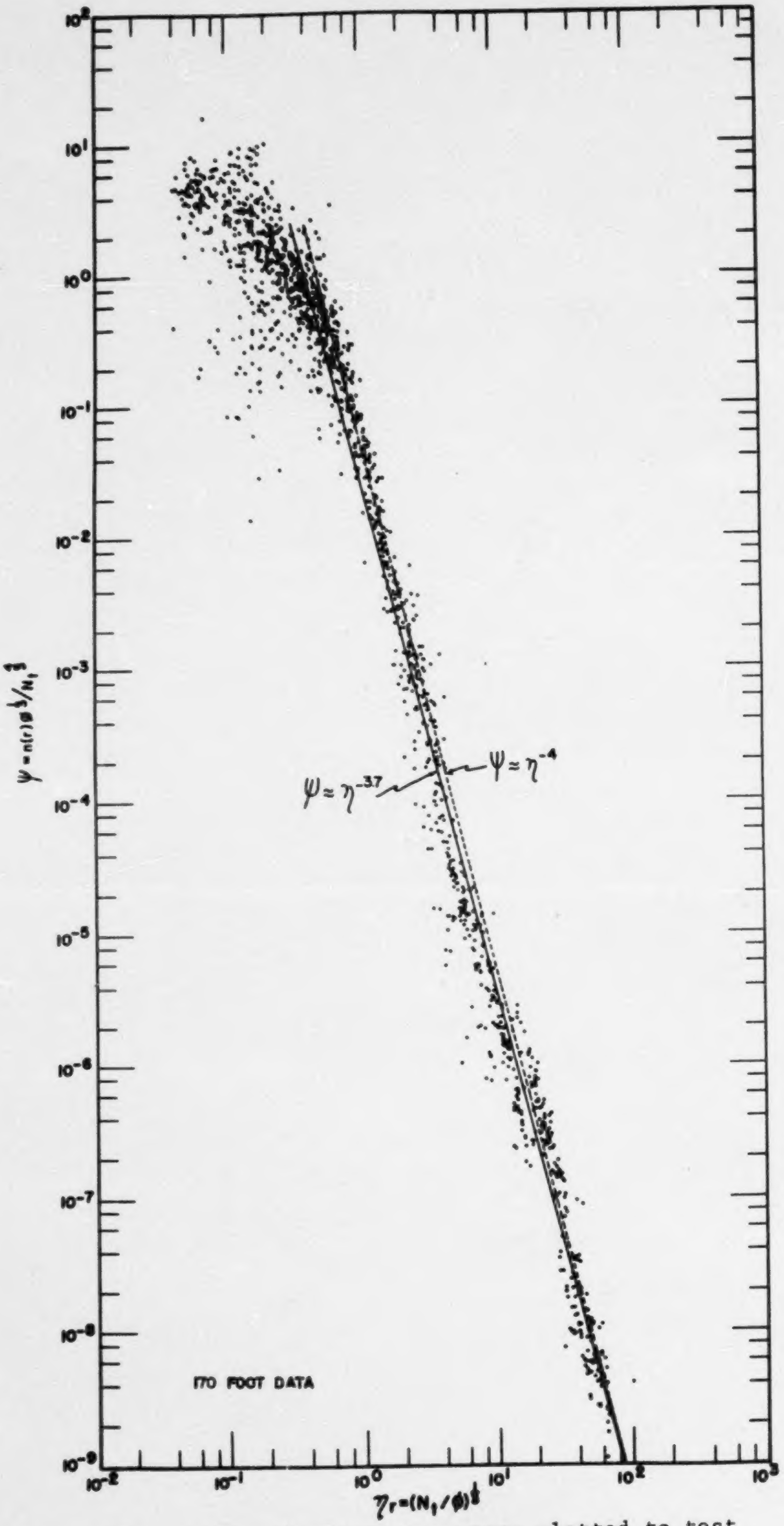


Figure 38. Dimensionless parameters plotted to test the self-preserving particle size distribution theory at the 170 foot level.

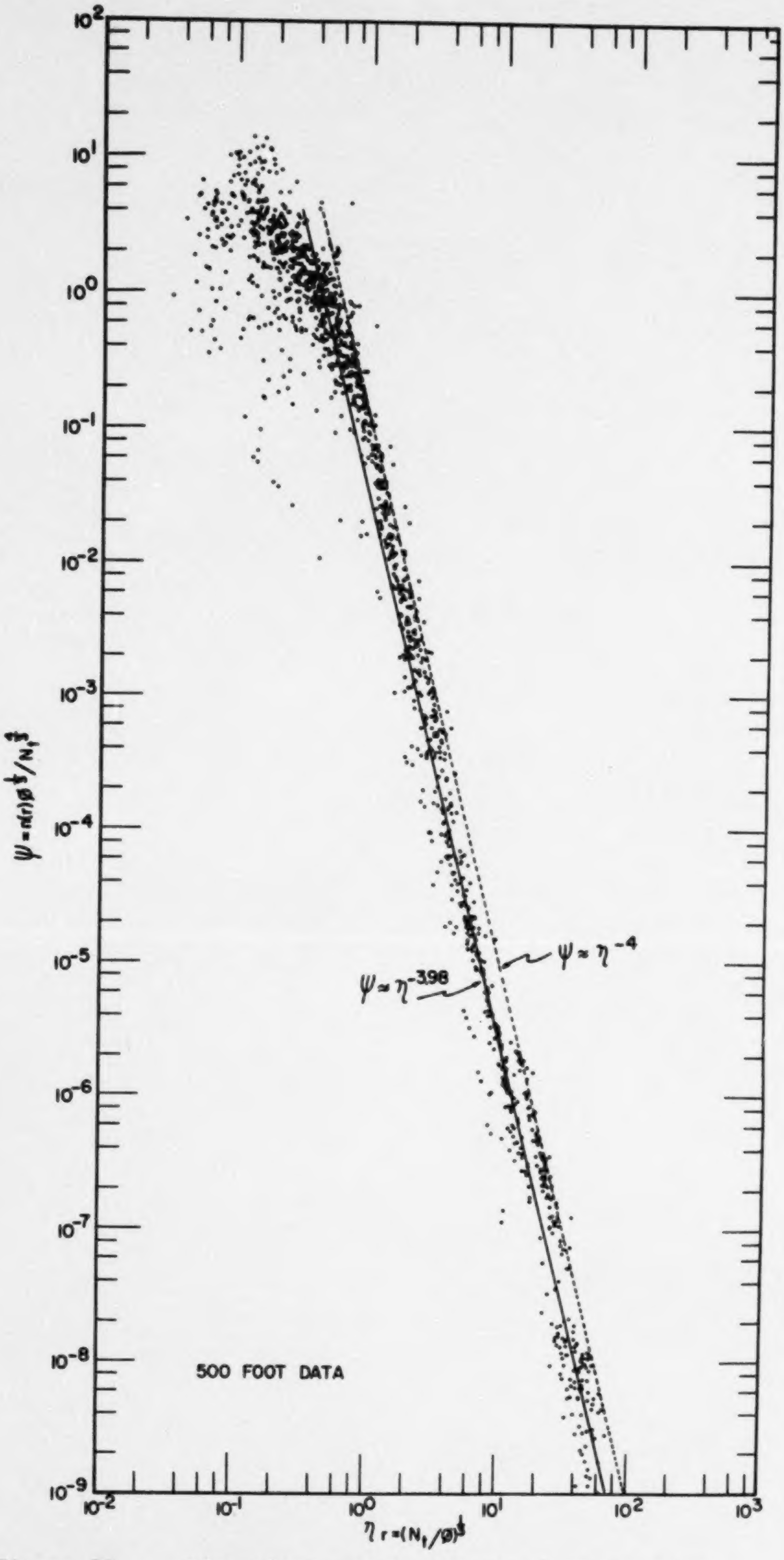


Figure 39. Dimensionless parameters plotted to test the self-preserving particle size distribution theory at the 500 foot level.

CHAPTER VI

VIABLE MICROORGANISMS IN THE URBAN ATMOSPHERE

The first impression gained from this study was the rather inconsistent and apparently undirected fluctuation of the viable airborne count from day to day. Eighty samples taken at each of three different altitudes (and at grade level) during 28 days from May 26 to November 7, 1967, suggested that there was no cyclical effect that could be attributed to season, and that there was no systematic pattern that could be used to predict the rise and fall of microbial concentration in the air.

These fluctuations are illustrated in Table VI. The mean viable counts (uncorrected for aerodynamic loss) were $38.4/\text{ft}^3$ at 70 feet, $32.7/\text{ft}^3$ at 170 feet and $22.4/\text{ft}^3$ at 500 feet. However, it is evident that the means alone do not describe the actual situation. Of greater importance is the range of counts observed, extending from a minimum of $3.5/\text{ft}^3$ (500 ft. level on November 7) to a maximum of $141/\text{ft}^3$ (70 ft. level on August 28). It can also be seen that the proportion of mold spores in the air was also quite variable. The mean mold count for the total period of study ranged from 69 to 76% at the various altitudes, but on a given day the values could be as low as 15% or as high as 95%.

Despite the lack of obvious pattern, Table VI provides a typical example of the actual microbiological situation which exists in the outside air of populated, industrially-oriented urban area. Wide fluctuations may well be characteristic of this type of environment, and the impression is left that simple "grab" samples or "average" counts, will not adequately reflect the situation. It was similarly evident that a monthly mean is misleading: The highest counts observed were recorded in August; on the other hand, some of the lowest counts were also recorded during that month.

Sampling Period		Meteorological Conditions									Viable Counts Colonies per ft^3 at					
		Wind[a] (knots)		Rainfall in Preceding		Humidity[b] (% RH)			Temp. (°F)	Temp.[c] Lapse (°F)	70 ft.		170 ft.		500 ft.	
Date	Hour			24 hr	7 days	S.P.	Range				Total	Mold %	Total	Mold %	Total	Mold %
May																
26	1400 - 1500	NW	13	0	0.05	NA	NA	NA	77	-3.75	58.9	22	58.6	26	18.7	28
June																
5	1130 - 1330[d]	ESE	5	0.74	0.74	NA	NA	NA	NA	NA	7.3	49	11.7	27	4.1	47
9	0930 - 1430	NE	5	0	1.85	56	100	61	NA	NA	50.5	91	49.3	88	16.3	84
23	0930 - 1430	N	8	0.25	1.13	36	100	42	60	-3.0	27.7	79	29.3	67	12.9	76
July																
3	1130 - 1330	NNW	14	0	0.70	42	96	48	NA	NA	50.1	40	43.3	37	20.1	47
7	1230 - 1330	SSW	13	0	0.70	51	84	44	85	-3.0	28.4	42	14.1	51	15.1	48
11	1030 - 1230	NNW	15	1.20	1.45	30	80	42	80	-3.0	63.9	90	45.1	90	28.9	87
18	1000 - 1200	SSE	3	0	0.95	50	75	37	76	-2.3	16.2	87	11.4	91	6.0	89
24	0930 - 1030	WNW	14	0	0	55	75	37	74	-2.7	38.3	90	23.9	93	15.5	89
31	1000 - 1200	NNE	4	0	0.05	56	NA	NA	77	-2.7	21.8	73	23.1	80	12.7	78
August																
4	0900 - 1100	NW	7	0.05	0.12	70	100	46	66	-2.7	50.7	50	41.3	55	25.3	62
7	1100 - 1200	N	3	1.75	2.02	75	100	70	63	-2.5	33.3	62	28.0	55	23.1	52
11	0900 - 1100	SSW	3	0	2.00	50	97	35	64	-1.7	7.3	75	6.5	71	5.6	72
14	1100 - 1200	SSW	10	0	0.23	58	84	34	75	-3.0	52.6	82	33.0	79	34.6	87
18	1330 - 1530	NNE	5	0	0	73	100	54	59	-3.0	20.5	50	17.6	45	14.4	51
21	1300 - 1500	NE	10	0	0	42	100	42	66	-3.5	39.7	80	32.5	86	23.7	84
25	1330 - 1530	SSW	6	0	0.80	52	81	47	80	-2.8	70.8	93	71.0	94	34.4	NA
28	1330 - 1400	S	13	0	2.29	38	90	32	77	-3.3	141.0	95	115.0	95	61.9	73
September																
5	1100 - 1300	SSW	6	0	0	42	98	38	71	-2.8	28.6	81	19.2	86	11.0	84
12	1000 - 1200	SSE	17	0	0	58	76	48	67	-3.2	66.3	72	59.0	78	62.7	75
15	1000 - 1200	SE	7	0	0.58	68	100	38	63	-2.5	56.8	75	67.6	72	49.8	69
18	0900 - 1100	SE	7	0.05	0.72	78	97	42	68	-2.0	42.1	69	44.4	71	32.8	66
22	0900 - 1100	SSE	8	0	0.15	67	100	36	54	-2.2	22.8	81	21.0	88	17.7	89
October																
3	0830 - 1030	E	9	0	0	71	92	40	57	-1.8	20.0	15	20.8	23	15.6	20
5	1540 - 1640	NNE	5	0	0	38	78	25	58	-3.0	36.6	58	26.6	68	20.9	62
10	1500 - 1700	NW	10	0	0.70	52	78	52	38	-2.2	28.1	48	19.4	50	19.6	54
November																
2	1300 - 1500	NNW	11	0	0.47	48	76	60	42	-3.0	26.7	65	9.3	41	15.7	41
7	1400 - 1500	SSE	7	0	0	46	96	40	33	-2.8	5.1	65	4.5	60	3.5	63

[a] Wind measured at 170-ft. level.
[b] S.P. = Relative humidity during sampling period. Range = Maxima and minima during preceding 24 hr.
[c] Temperature difference, T500 - T70 (adiabatic rate = -2.36).
[d] Rainfall occurred during sampling.

Table VI Results of sampling survey: concentration of viable airborne microorganisms at three altitudes and pertinent meteorological conditions prevailing.

It is noteworthy that the viable counts at each of the altitudes studied were closely related during any sampling period, even though there was a consistent diminution in count with altitude. Thus a high count at any altitude during any sampling day was reflected in a high count at the other altitudes during the same day; conversely, when the viable count fell, it fell at all altitudes simultaneously.

The microbiological data from this study were examined in the light of several meteorological variables in an attempt to explain the fluctuations observed. However, no clear or consistent correlation could be discerned between a variety of weather parameters and viable atmospheric counts. For example, Table VI shows that both high and low counts were encountered during "identical" wind, humidity, and temperature conditions. Conversely, diverse meteorological conditions were associated with biological findings.

Some idea of the qualitative distribution of the total viable count can be gained from Figure 40. The gradual diminution in count with increasing altitude, referred to previously, is quite discernible for all four groups of organisms and would certainly be expected over a 500 ft. profile. The remarkable feature of Figure 40, however, is the uniformity of ratios between the different types of microbes, and, in particular, the parallelism between mold counts and bacterial counts at each altitude. This uniformity suggests that the bacteria and molds, which together constitute > 90% of the total viable aerosol, might have originated from the same source and were certainly influenced by the same environmental parameters.

The yeast and actinomycete components seem to show some deviation from this parallel trend. These groups of organisms were consistently present, but in very small concentrations, and the apparent increase in yeast count at 170 ft. and actinomycete count at 500 ft.might suggest that they originated from sources

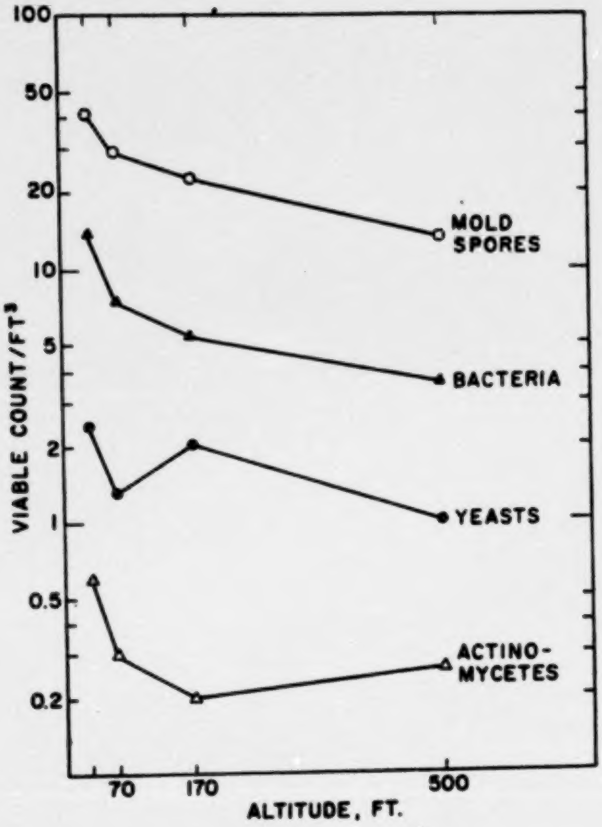


Figure 40. The influence of altitude on the concentration of different types of microorganisms (June-August 1967).

other than those that yielded the bacteria and molds. However, the actual numerical increases in both of these cases were so small, any attempt to draw a far-reaching conclusion from these data would be premature.

Further investigation and more detailed characterization of the molds and bacteria which constituted the great majority of the total viable population in the atmosphere. Bacterial colonies were characterized during June, July, and August; molds were characterized during September, October, and November.

The morphology of the bacteria isolated is summarized in Table VII. As in the case of the yeasts and actinomycetes mentioned above, the numerical differences are too small to lend themselves to theoretical speculation. It does appear that lower altitudes are characteristically more heavily populated with gram-positive bacilli, whereas there is a more uniform mix at the highest altitude. This might have something to do with the origin (e.g., soil, street traffic, industrial pollution, agriculture, etc.) of the different morphological types. However, until we learn something about the numerical differences that are accountable simply to random variation in this work, we will not be able to ascribe significance to the values shown.

Table VII. Morphological types of bacteria encountered at different altitudes during June - August 1967.

	Count per Cubic Foot at Altitude			
Bacterial Type	35 ft	70 ft	170 ft	500 ft
Gram-positive bacilli (sporeformers)	10.3	7.6	3.5	2.0
Gram-positive bacilli (nonsporeformers)	11.5	6.8	5.8	3.7
Gram-positive cocci	7.1	3.0	1.9	1.3
Gram-negative bacilli	6.8	3.9	2.4	1.6
Diphtheroids	5.9	3.1	2.7	1.9

Figure 41 shows the relative concentrations of five identifiable mold genera present in the atmosphere at four different altitudes. The observation that Cladosporium so comprises 60 - 70% of all the molds encountered, coupled with the previous observation (see Figure 40) that the molds themselves represent about 69 - 76% of the total viable count at each altitude, indicates that Cladosporium spores are, by far, the most predominant microbial particles in the atmosphere.

Figure 42 summarizes the particle size classification of the viable microorganisms trapped in our study. It can be seen that at "grade level" most of the viable particles (or particles with which viable organisms were associated) were large; i.e., > 5 μ. This is probably a reflection of the transient street dust generated by traffic and wind. Most of these large particles did not reach the 70 ft. level. At 70, 170, and 500 ft. altitudes, the particle size distributions were nearly identical. Most of the viable particles were in the 3 - 5 μ range and were fairly normally distributed on both sides of this mode. Considering the data presented previously about the predominance of Cladosporium spores, this would be expected, since these spores have dimensions in the 3 - 5 μ range. More significantly, particles with diameters of 3 - 5 μ are the ones that classically concern industrial hygienists because of their propensity for pulmonary retention.

It should be noted that the data presented above were not corrected for possible wall loss in the sampling system. Consequently, some bias might have been introduced against the larger size particles. However, applying the theoretical corrections, previously cited, to the viable particle size distribution observed, it was seen that for the 500 ft.level only about a 10% increase in total counts would have been expected if not all losses occurred.

The numerical difference in recovered viable particles between the 70 and 500 ft.levels could possibly reflect an artifact introduced by anisokinetic sampling from air masses having differing velocities. This problem was considered

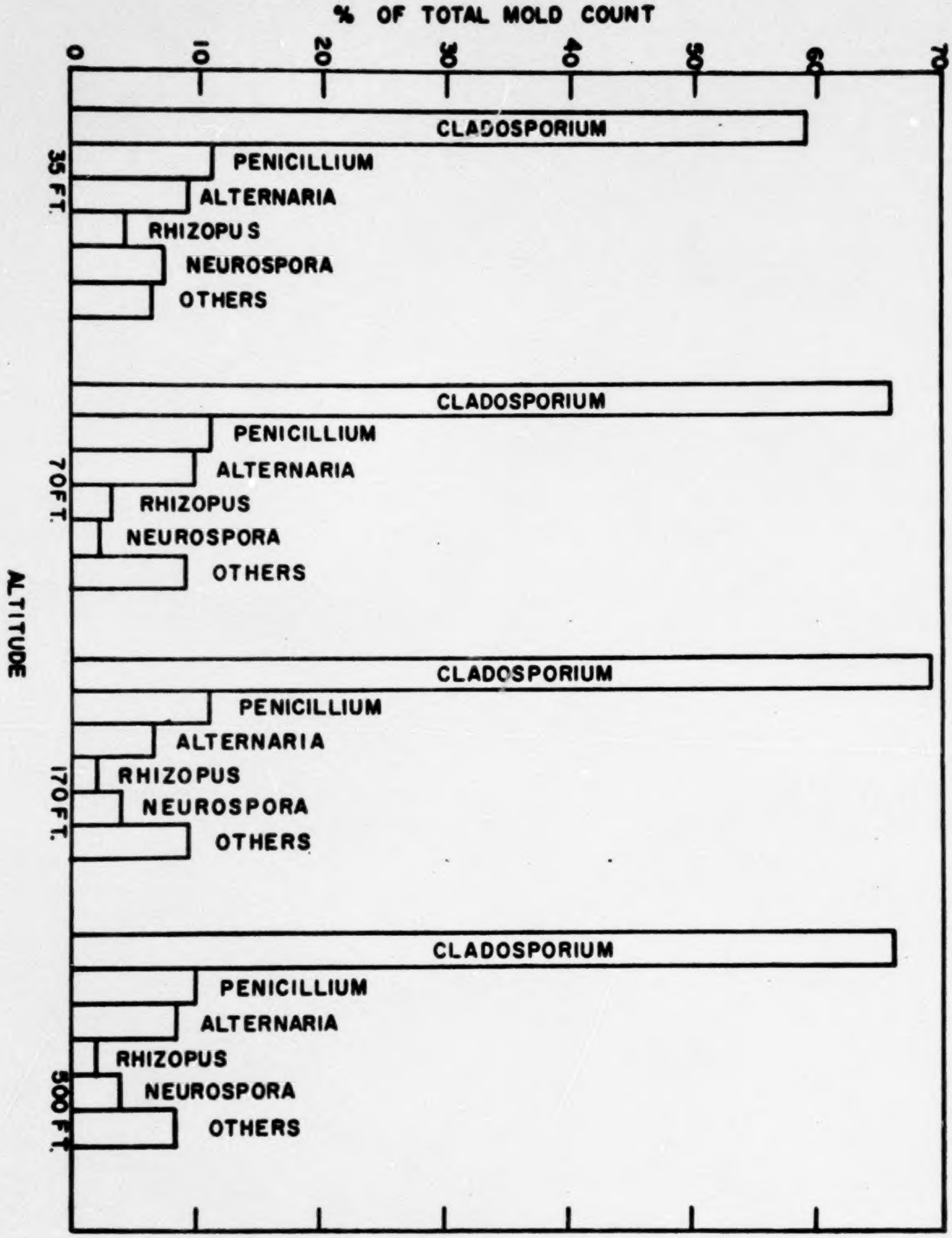


Figure 41. Predominant genera of fungi encountered at different altitudes (September-November 1967).

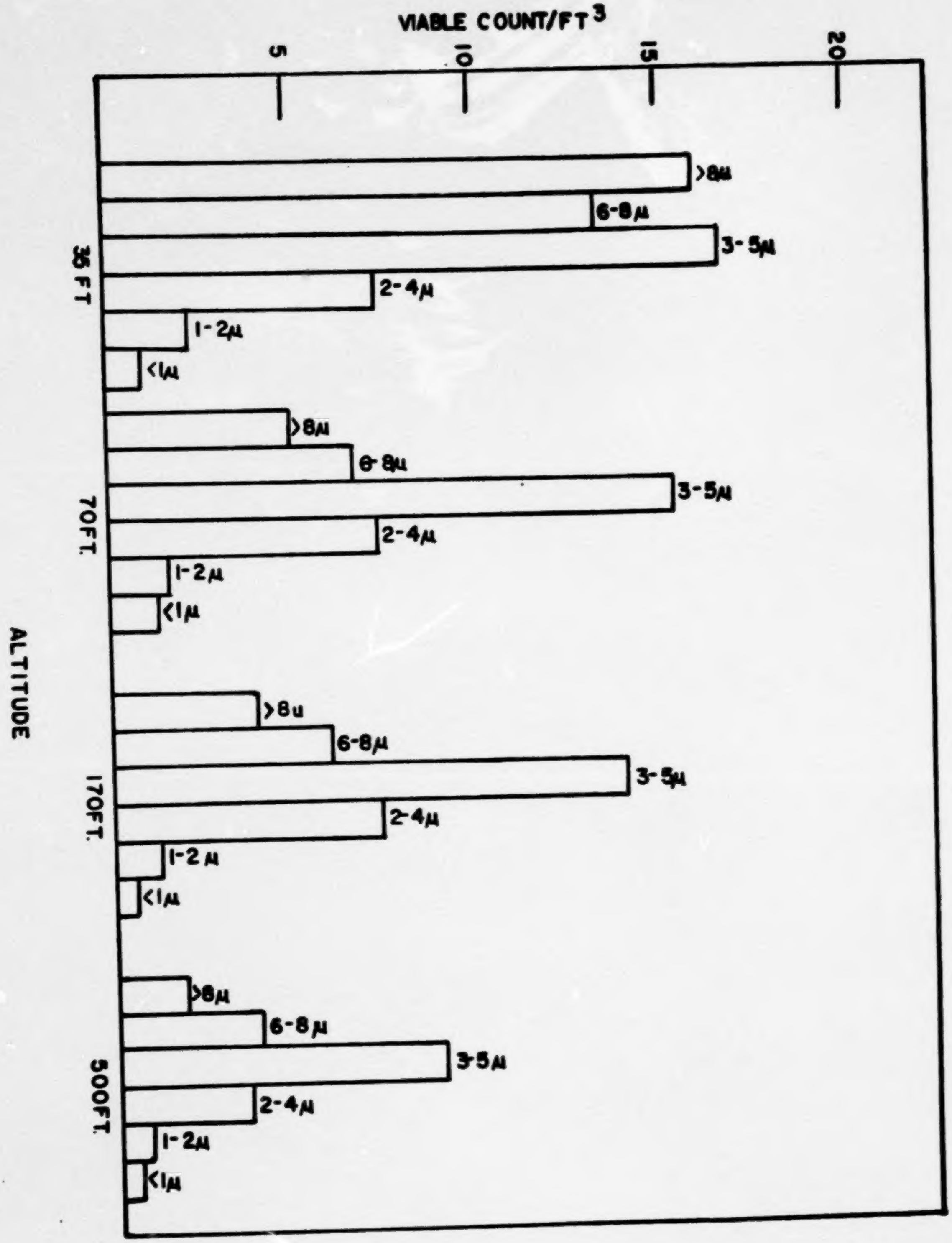


Figure 42. Size classification of viable particles encountered at different altitudes (May-November 1967).

by Peterson and Paulus who showed, in a series of wind tunnel tests, that the sampling head performed within ±3% of the isokinetic value for a variety of particle sizes. In general, physical errors in this sampling procedure are probably small compared with the potential uncertainties introduced by the biological assay. Variations in the growth media, incubation temperature, and colony enumeration can all introduce more serious biases in the final results than sampling errors as such.

The Royco Model 220 optical particle counter (which counts and sizes particles greater than 0.5 micron) was used to determine the total number of particles in the sampled air. It must be mentioned that the particle sizes measured are not necessarily those of the microorganisms themselves but often size of the particles with which the viable organisms are associated in the atmosphere. The number of colonies appearing on an agar surface (Casella) was compared with the total particulate count and it appeared that less than one particle in a thousand had associated with it a viable microorganism. Comparisons using the Anderson sampler showed that over two percent of the particles larger than four microns in diameter had microbes associated with them but this proportion dropped off sharply with decreasing particle size. The overall value for particles larger than 0.5 microns was approximately 0.5 viable colonies formed per 1,000 particles counted.

For each sampling period during the investigation an appraisal was made of the air mass located in the Twin Cities area. By examining United States weather maps for several days immediately preceding and following the date and time of the sampling, it was possible to trace the motion of the air pracel of interest. By this means it was also possible to define those instances when a new and distinct air system arrived in the region during the interval between two consecutive sampling periods. The micrometeorological measurements made at the sampling location could be used to pinpoint quite exactly the movement into the area of a particular weather system. A sudden change in wind direction or temperature often signaled the entry of a new system into the area.

The "polar" air masses originate in Canada and are generally associated with fair, cool conditions in the Twin City area. The southern or "Gulf" air mass contains warm, moist air and is often associated with precipitation. As can be seen the two types of circulation do not display a strikingly different aeroflora. The means were not significantly different when tested by a statistical t-test. This suggests that any marked changes in the aerobiological picture would probably be due to other factors than air mass origin.

A simple averaging procedure, although certainly valuable, often seems to obscure more than clarify the complex relationships between airborne microbes and the environment. An investigation of this sort gives some indication of the potential value and limitations in using general motions of the atmosphere to explain, or possibly predict, the concentrations of microbes found in the air. At least at this sampling site, certain limitations appeared to restrict the utility of this method. While in certain situations a fairly clear relationship was evident between air masses and airborne microbes, in other cases such a variety of other factors appeared that no concise statements were possible. It may be at other locations, or in more specialized studies where a single type of microorganisms may be of interest, that the study of atmosphere motions will be more fruitful.

The numbers of viable organisms in the air masses studied varied quite markedly between sampling periods. At their maximum, the counts were much higher than would be expected, particularly at the 500 ft. level. Counts of 60 - 120 viable organisms/ft^3 can be better appreciated when it is pointed out that normal levels in occupied rooms rarely exceed 50/ft^3.

The distribution of microbial types was characteristic of "extramural air". Molds contributed from 2/3 to 3/4 of the total population, and Cladosporium spores constituted between 60 and 70% of the mold count. The high mold count might have resulted from the grain handling activities of the mills and elevators in the proximity of the KSTP tower, since it is well known that fungi are the natural and predominant contaminants on cereal grains. However, it should be noted that many aerobiological surveys of uninhabited regions (e.g., the North Atlantic, the Arctic, the stratosphere) also report Cladosporium as the most characteristic genus of the viable microflora.

Another objective of this study was to ascertain the influence of certain key meteorological parameters on microbial types and numbers. Wind speed and direction were considered as likely influences on airborne populations. If there were, in the proximal vicinity of the sampling site, any specific sources of microbial pollutants or any significant "collection sinks" changes of wind direction should create an identifiable pattern of microbiological changes in types and or numbers. This did not occur. Thus it can be surmised that with respect to microorganisms, the sampling station is located in a relatively homogeneous region with no geographical discontinuities. The fluctuations that were observed were probably due to sporadic and random releases of contaminated particles, unrelated to wind direction. The releases could have been local or distant, but were not identified in this study.

Wind speed would influence atmospheric microbial populations in two ways. First, wind provides as aero-dynamic force to aerosolize fungal spores and bacterial laden dust particles from the ground or other surfaces, with higher wind speeds leading to higher viable concentrations. Second, the increased turbulence associated with increased wind speeds, especially in an area of considerable topographical roughness (due to trees and buildings), might be expected to induce a greater uniformity of counts at the different elevations sampled. Neither of these effects was evident. The uniformity or non-uniformity of counts at different altitudes was independent of wind speed.

The amount of soil moisture present influences the growth of microorganisms just as it affects macroscopic vegetation, with high moisture levels resulting in high microbial counts. An opposing influence of moisture on airborne concentrations of either viable or nonviable particulates relates to the difficulty of aerosolizing individual particles from their source. But no obvious relationship could be seen between rainfall in the 24 hour and 7 day period prior to sampling and the atmospheric microbial concentrations. It should be noted that samples taken during a rainfall showed considerably reduced counts, apparently due to the "washing out" action of the raindrops. Samples taken within hours after precipitation, however, showed values within the usual range and were neither higher nor lower than those taken at other times. It may be that the two conflicting mechanisms were in operation: moisture leading to the high surface populations, and dryness resulting in easier aerosolization, both interacting to obscure the actual effect of rainfall as a factor in the atmospheric concentrations.

Temperature and relative humidity are also known to be important factors in the life and growth of microbial populations. However, there appeared to be little relationship between these variables and the observed airborne concentrations.

In addition to the temperature itself, the temperature lapse rate might influence the viable concentration at different altitudes. As this is a measure of atmospheric stability, isothermal or inversion conditions should show a more or less stratified pattern of microorganisms by elevation. Unfortunately, only four sampling periods showed lapse rates less than the dry adiabatic rate, and even these periods did not approach inversion conditions. It was, therefore, not too surprising that the lapse rates observed in this study offered no significant insight into the concentration or distribution of microorganisms in the atmosphere. The favorable conditions for vertical mixing did indicate a possible explanation for the observed lack of large variation in microbial concentration with height. A study embracing a greater variety of temperature lapse conditions will be necessary to delineate adequately the effect of this factor in terms of viable particulates.

It should be recognized that each of the six meteorological parameters studied could have a different quantitative and qualitative effect on those factors which influence the viable population. Furthermore, there is undoubtedly some type of confounding interaction among the six meteorological parameters themselves, leading to difficulty in identifying specific cause and effect relationships.

It was possible to show that relatively large concentrations of viable microorganisms might be present in an urban atmosphere. Because of their small size they can be considered stable aerosols which can be transported great distances. Also because of their characteristic size, they will be inhaled and retained in the lungs. And because the predominant organisms are identifiable as spoilage and allergy agents, the dimensions of the problem, from the point of view of air pollution, can now be better appreciated.

CHAPTER VII

SUMMARY AND CONCLUSIONS

A broad size spectrum particle counting and sizing system was developed and automated to continuously characterize suspended particulates. Initial performance of the particle counting and sizing system has proved it to be effective in sizing and counting heterogeneous aerosols. It is capable of providing particle count and size data over the particle size range from 0.001 to about 10 microns with an apparent accuracy of plus or minus 20 percent of the indicated value. It is stable, responds rapidly and most important it is automatic.

Aerosol research in the area of air pollution and combustion product particle sizing and counting, meteorological-particle phenomena and filter retention studies can now be more readily and accurately performed. In addition, when the EPC is operated as a classifier, additional areas of research might include cumulative number-size particle chemical analysis, natural charge on particle studies and various respiratory system particle retention phenomena.

As developed and automated, the broad size spectrum particle counting and sizing system was combined with meteorological instrumentation and located on a local television tower to continuously monitor urban atmospheric aerosol and micrometeorological parameters. As installed, the combined system was capable of measuring and recording particle number and size, wind speed and direction, vertical temperature distributions, relative humidity, precipitation, barometric pressure, direct radiation, smoke spot and SO_2 concentration.

Particle data were obtained by sampling the atmosphere at three different altitudes above ground level. This information was used to construct time dependent particle number-size distributions for each level. A total of 360 distributions were constructed and reviewed on the basis of the measured meteorological parameters. Measured variations or changes in the particle number and size data with time were specifically reviewed with reference to the measured temperature distributions, direct radiation and wind speed. It was found that air mass stability measured as a function of the vertical temperature distribution influenced the particle number concentration to the greatest extent. Particle number concentration decreased more rapidly with height during inversion conditions than during any other less stable air mass period. Total number concentrations found to be higher during periods of unstable air. This was interpreted as being caused by increased mixing of highly polluted ground level air with the aged aerosol of the upper atmosphere. The effect of direct radiation was noted during sampling periods in which the amount of direct radiation reaching the lower atmosphere or earth surface varied during short intervals of time. It was found that during decreased radiation the number concentration decreased and with increased radiation the number of particles within the size range from 0.1 to 0.5 micron showed the greatest number increase.

The particle number-size measurements were compared to the previously reported data and reviewed on the basis of the self-preserving number-size distribution phenomenon first noted and described by Junge (23). In 1954, Junge summarized the results of his measurements with the following statement:

> "The available data seem to indicate that the maximum number concentration is located in the size range between 10^{-5} and 10^{-6} cm. radius, and that the number concentration drops to zero between 10^{-6} and 10^{-7} cm. radius. The size range greater than 10^{-5} cm. can be well represented by a power law which seems to hold for large parts of the world. It can be shown further, where ion and nuclei counts or other electrical data are available from a large number of places all over the world, that the average radius of all particles decreases when the total number decreases. This can be explained by coagulation processes." (23)

The number-size distributions determined in this study are different from that of Junge in that the overall number magnitude is greater, the function $n(r) \approx r^{-4}$ does not describe as large a section of the distribution curve and in addition, many of the curves are bimodal. It was found in this study that the function $n(r) \approx r^{-4}$ is approached at higher altitudes. According to the results of this study, the number concentration does not drop to zero between 10^{-6} and 10^{-7} centimeter radius as in most distributions the number concentration is increasing in this size range. It was also found that when the total number of particles decreases the average radius of the particle number-size distribution increases. This phenomenon was noted at the 500 foot level during each inversion condition.

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APPENDIX A

Particle Number-Size Data for Specific Sampling Periods

DATE	2-6-67															2-6-67		
TIME (mid sample)	0824	0840	0856	0912	0928	0944	1000	1016	1032	1048	1104	1120	1136	1152	1208	2205	2215	2225
PARTICLES / CM^3 (diameter-micron)																		
TOTAL, 0.002-8.0																		
70 feet	7.94×10^{5}			7.52×10^{5}			4.77×10^{5}			4.99×10^{5}			2.18×10^{5}			7.87×10^{5}		
170 feet		2.08×10^{5}			2.85×10^{5}			4.17×10^{5}			1.87×10^{5}			1.63×10^{5}			1.97×10^{5}	
500 feet			6.17×10^{3}			5.46×10^{4}			4.21×10^{5}			1.80×10^{5}			1.09×10^{5}			3.92×10^{4}
RANGE, 0.002-0.02																		
70 feet	5.72×10^{5}			4.50×10^{5}			3.23×10^{5}			3.18×10^{5}			1.51×10^{5}			3.14×10^{5}		
170 feet		1.00×10^{5}			9.37×10^{4}			1.98×10^{5}			1.16×10^{5}			1.33×10^{5}			1.02×10^{5}	
500 feet			1.66×10^{3}			3.64×10^{4}			3.58×10^{5}			8.55×10^{4}			1.09×10^{5}			1.73×10^{4}
RANGE, 0.02-0.03																		
70 feet	9.91×10^{4}			9.56×10^{4}			1.58×10^{4}			1.20×10^{5}			1.43×10^{4}			1.05×10^{5}		
170 feet		1.21×10^{4}			3.20×10^{4}			6.68×10^{4}			5.40×10^{3}			4.03×10^{3}			6.89×10^{3}	
500 feet			2.18×10^{2}			2.78×10^{3}			5.42×10^{3}			2.72×10^{4}			2.90×10^{4}			4.80×10^{3}
RANGE, 0.03-0.04																		
70 feet	1.29×10^{4}			2.38×10^{4}			1.03×10^{4}			3.21×10^{3}			7.45×10^{3}			4.28×10^{4}		
170 feet		3.86×10^{3}			3.41×10^{4}			1.93×10^{4}			1.22×10^{4}			3.86×10^{3}			1.80×10^{4}	
500 feet			4.30×10^{1}			2.18×10^{3}			6.44×10^{3}			1.71×10^{4}			6.27×10^{3}			3.09×10^{3}
RANGE, 0.04-0.06																		
70 feet	3.18×10^{4}			8.50×10^{4}			4.49×10^{4}			1.63×10^{4}			1.56×10^{4}			1.18×10^{5}		
170 feet		3.77×10^{4}			7.00×10^{4}			4.54×10^{4}			2.54×10^{4}			6.67×10^{3}			2.82×10^{4}	
500 feet			1.04×10^{3}			1.09×10^{3}			9.08×10^{3}			2.61×10^{4}			8.16×10^{3}			4.79×10^{3}
RANGE, 0.06-0.08																		
70 feet	2.55×10^{4}			4.01×10^{4}			3.12×10^{4}			1.34×10^{4}			1.10×10^{4}			8.79×10^{4}		
170 feet		1.52×10^{4}			2.16×10^{4}			2.97×10^{4}			1.17×10^{4}			3.34×10^{3}			1.41×10^{4}	
500 feet			9.88×10^{2}			1.41×10^{3}			4.24×10^{3}			1.06×10^{4}			4.71×10^{3}			3.59×10^{3}
RANGE, 0.08-0.1																		
70 feet	3.09×10^{4}			2.35×10^{4}			2.02×10^{4}			1.38×10^{4}			1.10×10^{4}			6.82×10^{4}		
170 feet		1.47×10^{4}			1.47×10^{4}			2.44×10^{4}			1.17×10^{4}			3.34×10^{3}			1.28×10^{4}	
500 feet			7.17×10^{2}			1.65×10^{3}			7.12×10^{3}			1.06×10^{4}			4.71×10^{3}			3.16×10^{3}
RANGE, 0.1-0.2																		
70 feet	2.06×10^{4}			2.01×10^{4}			2.71×10^{4}			1.29×10^{4}			7.47×10^{3}			4.48×10^{4}		
170 feet		2.13×10^{4}			1.42×10^{4}			2.91×10^{4}			7.46×10^{3}			6.95×10^{3}			1.29×10^{4}	
500 feet			1.02×10^{3}			8.48×10^{3}			2.79×10^{4}			5.50×10^{3}			3.79×10^{3}			2.08×10^{4}
RANGE, 0.2-0.3																		
70 feet	7.88×10^{2}			1.19×10^{4}			3.15×10^{3}			8.44×10^{2}			9.41×10^{2}			4.73×10^{3}		
170 feet		2.41×10^{3}			4.65×10^{3}			3.15×10^{3}			4.95×10^{2}			1.39×10^{2}			1.60×10^{3}	
500 feet			4.17×10^{2}			3.71×10^{2}			2.05×10^{3}			7.65×10^{2}			3.23×10^{2}			1.73×10^{2}
RANGE, 0.3-0.5																		
70 feet	4.89×10^{2}			1.08×10^{3}			1.66×10^{3}			3.28×10^{2}			1.97×10^{2}			1.82×10^{3}		
170 feet		5.02×10^{2}			2.28×10^{2}			1.17×10^{3}			3.63×10^{2}			2.93×10^{2}			2.37×10^{2}	
500 feet			7.70×10^{1}			2.30×10^{2}			9.84×10^{2}			2.80×10^{2}			3.83×10^{2}			6.10×10^{1}
RANGE, 0.5-1.0																		
70 feet	2.00×10^{1}			1.50×10^{1}			2.90×10^{1}			4.70			2.90			3.17×10^{1}		
170 feet		3.54×10^{1}			1.48×10^{1}			3.08×10^{1}			3.00			4.00			1.01×10^{1}	
500 feet			0.91			4.40			1.78×10^{1}			4.32			5.02			1.14
RANGE, 1.0-2.0																		
70 feet	3.75			1.90			2.60			0.96			0.56			3.82		
170 feet		4.10			1.66			2.88			0.67			1.04			1.12	
500 feet			0.24			0.69			2.53			1.08			0.75			0.16
RANGE, 2.0-8.0																		
70 feet	0.31			0.29			0.29			0.33			0.13			0.12		
170 feet		0.32			0.23			0.36			0.16			0.31			0.10	
500 feet			0.09			0.13			0.35			0.37			0.17			0.02

Table A-I Particle number data for the period 0824-1208 and 2205-2225, 6 February 1967.

DATE	2-6-67						2-7-67												
TIME (mid sample)	2235	2245	2255	2305	2315	2325	0825	0835	0845	0855	0905	0912	0917	0925	0935	0945	0955	1005	1015
PARTICLES / CM^3 (diameter-micron)																			
TOTAL, 0.002-8.0 70 feet 170 feet 500 feet	$3.64x10^5$	$2.31x10^5$	$3.97x10^4$	$6.71x10^5$	$2.08x10^5$	$2.66x10^4$	$1.79x10^5$	$9.14x10^4$	$2.64x10^4$	$2.15x10^5$	$1.01x10^5$			$6.54x10^5$	$1.84x10^5$	$7.39x10^4$	$2.29x10^5$	$1.13x10^5$	$7.16x10^4$
RANGE, 0.002-0.02 70 feet 170 feet 500 feet	$1.56x10^5$	$8.84x10^4$	$1.52x10^4$	$5.28x10^5$	$2.52x10^4$	$4.43x10^3$	$1.94x10^4$	$4.67x10^4$	$3.09x10^3$	$1.14x10^5$	$6.49x10^4$	Temperature inversion passed above the 500 foot level during the sample period and the Electrical Particle Counter results were not valid. Average of Nuclei Counts during 9:10-9:15 was 15,053 and from 9:15-9:20 it was 29,507. This included particles in the range from 0.002 to 0.1 micron.		$5.41x10^5$	$1.32x10^5$	$2.70x10^4$	$1.90x10^5$	$7.90x10^4$	$3.83x10^4$
RANGE, 0.02-0.03 70 feet 170 feet 500 feet	$4.65x10^4$	$2.33x10^4$	$2.12x10^3$	$3.55x10^4$	$8.18x10^4$	$8.10x10^3$	$7.81x10^4$	$8.69x10^3$	$2.24x10^3$	$5.49x10^4$	$4.97x10^3$			$1.58x10^4$	$9.31x10^3$	$4.67x10^3$	$4.34x10^3$	$5.59x10^3$	$3.74x10^3$
RANGE, 0.03-0.04 70 feet 170 feet 500 feet	$2.72x10^4$	$1.93x10^4$	$3.09x10^3$	$6.55x10^3$	$1.93x10^4$	$3.44x10^3$	$2.82x10^4$	$6.86x10^3$	$1.28x10^3$	$7.28x10^3$	$5.15x10^3$			$2.70x10^4$	$7.72x10^3$	$5.37x10^3$	$3.42x10^3$	$5.57x10^3$	$3.44x10^3$
RANGE, 0.04-0.06 70 feet 170 feet 500 feet	$4.59x10^4$	$4.18x10^4$	$8.73x10^3$	$3.68x10^4$	$3.63x10^4$	$5.76x10^3$	$3.04x10^4$	$1.21x10^4$	$7.08x10^3$	$1.57x10^4$	$1.06x10^4$			$4.27x10^4$	$1.33x10^4$	$1.24x10^4$	$8.47x10^3$	$7.58x10^3$	$8.19x10^3$
RANGE, 0.06-0.08 70 feet 170 feet 500 feet	$2.51x10^4$	$2.16x10^4$	$4.58x10^3$	$1.90x10^4$	$2.01x10^4$	$2.41x10^3$	$8.92x10^3$	$6.44x10^3$	$4.66x10^3$	$8.54x10^3$	$4.95x10^3$			$1.23x10^4$	$6.19x10^3$	$8.92x10^3$	$8.67x10^3$	$5.45x10^3$	$5.95x10^3$
RANGE, 0.08-0.1 70 feet 170 feet 500 feet	$4.01x10^4$	$1.95x10^4$	$2.85x10^3$	$1.20x10^4$	$1.31x10^4$	$1.42x10^3$	$7.15x10^3$	$5.46x10^3$	$4.64x10^3$	$6.72x10^3$	$5.80x10^3$			$7.94x10^3$	$7.94x10^3$	$7.94x10^3$	$7.32x10^3$	$4.27x10^3$	$5.70x10^3$
RANGE, 0.1-0.2 70 feet 170 feet 500 feet	$2.09x10^4$	$1.52x10^4$	$2.76x10^3$	$2.88x10^4$	$1.08x10^4$	$9.86x10^2$	$5.96x10^3$	$4.48x10^3$	$2.75x10^3$	$5.73x10^3$	$4.07x10^3$		$3.13x10^3$	$6.33x10^3$	$6.18x10^3$	$6.49x10^3$	$5.98x10^3$	$5.19x10^3$	$5.54x10^3$
RANGE, 0.2-0.3 70 feet 170 feet 500 feet	$1.98x10^3$	$1.91x10^3$	$2.55x10^2$	$3.42x10^3$	$8.55x10^2$	$1.73x10^1$	$5.40x10^2$	$5.33x10^2$	$5.40x10^2$	$6.75x10^2$	$3.75x10^2$		$3.37x10^2$	$7.69x10^2$	$7.12x10^2$	$8.85x10^2$	$8.70x10^2$	$5.02x10^2$	$5.62x10^2$
RANGE, 0.3-0.5 70 feet 170 feet 500 feet	$5.45x10^2$	$2.33x10^2$	$1.21x10^2$	$1.06x10^3$	$6.29x10^2$	1.40	$1.82x10^2$	$1.26x10^2$	$8.80x10^1$	$3.95x10^2$	$1.62x10^2$		9.54	$3.35x10^2$	$1.76x10^2$	$1.90x10^2$	$2.70x10^2$	$1.30x10^2$	$1.76x10^2$
RANGE, 0.5-1.0 70 feet 170 feet 500 feet	$2.75x10^1$	$3.23x10^1$	1.36	$2.72x10^1$	2.18	0.69	5.71	4.00	3.66	5.48	2.62	1.14	3.40	4.15	4.58	5.47	3.24	2.68	3.25
RANGE, 1.0-2.0 70 feet 170 feet 500 feet	3.05	1.74	0.17	2.68	1.12	0.09	0.67	0.45	0.18	0.63	0.30	0.23	0.91	0.48	0.45	0.81	3.53	0.31	0.55
RANGE, 2.0-8.0 70 feet 170 feet 500 feet	0.09	0.07	0.01	0.09	0.04	0.02	0.08	0.05	0.02	0.07	0.04	0.03	0.15	0.08	0.08	0.14	0.06	0.05	0.09

Table A-II Particle number data for the periods 2235-2325, 6 February 1967 and 0825-1915, 7 February 1967.

DATE	2-22-67					
TIME (mid sample)	1055 1100 1105	1155 1200 1205	1255 1300 1305	1355 1400 1405	1455 1500 1505	1555 1600 1605
PARTICLES / CM^{3} (diameter-micron)						
TOTAL, 0.002-8.0 70 feet 170 feet 500 feet	$1.86x10^{5}$ $2.13x10^{5}$ $8.24x10^{4}$	$1.92x10^{5}$ $1.55x10^{5}$ $7.96x10^{4}$	$2.55x10^{5}$ $1.81x10^{5}$ $1.21x10^{5}$	$3.42x10^{6}$ $5.66x10^{4}$ $7.94x10^{4}$	$2.62x10^{5}$ $1.84x10^{5}$ $5.11x10^{4}$	$1.65x10^{5}$ $1.25x10^{5}$ $7.05x10^{4}$
RANGE, 0.002-0.02 70 feet 170 feet 500 feet	$1.18x10^{5}$ $1.74x10^{5}$ $3.83x10^{4}$	$1.22x10^{5}$ $1.14x10^{5}$ $6.13x10^{4}$	$2.03x10^{5}$ $1.48x10^{5}$ $1.01x10^{5}$	$3.33x10^{6}$ $2.35x10^{4}$ $5.85x10^{4}$	$1.99x10^{5}$ $1.46x10^{5}$ $1.57x10^{4}$	$1.16x10^{5}$ $8.66x10^{4}$ $4.15x10^{4}$
RANGE, 0.02-0.03 70 feet 170 feet 500 feet	$2.62x10^{4}$ $9.56x10^{3}$ $1.18x10^{4}$	$3.10x10^{4}$ $5.77x10^{3}$ $4.36x10^{3}$	$3.19x10^{4}$ $5.52x10^{3}$ $4.05x10^{3}$	$4.26x10^{4}$ $1.20x10^{4}$ $6.61x10^{3}$	$2.90x10^{4}$ $1.12x10^{4}$ $1.71x10^{4}$	$2.60x10^{4}$ $1.40x10^{4}$ $8.79x10^{3}$
RANGE, 0.03-0.04 70 feet 170 feet 500 feet	$1.57x10^{4}$ $9.35x10^{3}$ $6.53x10^{3}$	$2.12x10^{4}$ $9.07x10^{3}$ $2.62x10^{3}$	$2.57x10^{2}$ $5.02x10^{3}$ $4.00x10^{3}$	$1.77x10^{4}$ $5.66x10^{3}$ $4.55x10^{3}$	$1.22x10^{4}$ $6.60x10^{3}$ $5.54x10^{3}$	$9.72x10^{3}$ $7.29x10^{3}$ $5.16x10^{3}$
RANGE, 0.04-0.06 70 feet 170 feet 500 feet	$1.20x10^{4}$ $1.33x10^{4}$ $1.01x10^{4}$	$9.17x10^{3}$ $1.44x10^{4}$ $4.39x10^{3}$	$7.60x10^{3}$ $1.38x10^{4}$ $6.76x10^{3}$	$1.64x10^{4}$ $8.58x10^{3}$ $5.13x10^{3}$	$1.27x10^{4}$ $1.21x10^{4}$ $6.79x10^{3}$	$7.23x10^{3}$ $9.61x10^{3}$ $5.61x10^{3}$
RANGE, 0.06-0.08 70 feet 170 feet 500 feet	$4.86x10^{3}$ $2.65x10^{3}$ $7.23x10^{3}$	$1.81x10^{3}$ $5.55x10^{3}$ $1.41x10^{3}$	$5.00x10^{3}$ $3.15x10^{3}$ $2.06x10^{3}$	$2.73x10^{3}$ $2.90x10^{3}$ $1.41x10^{3}$	$3.72x10^{3}$ $3.37x10^{3}$ $2.65x10^{3}$	$1.34x10^{3}$ $1.96x10^{3}$ $3.17x10^{3}$
RANGE, 0.08-0.1 70 feet 170 feet 500 feet	$4.64x10^{3}$ $2.02x10^{3}$ $5.19x10^{3}$	$1.45x10^{3}$ $2.71x10^{3}$ $1.93x10^{3}$	$3.71x10^{3}$ $2.04x10^{3}$ $1.47x10^{3}$	$3.68x10^{3}$ $2.06x10^{3}$ $1.10x10^{3}$	$2.12x10^{3}$ $2.20x10^{3}$ $1.81x10^{3}$	$1.53x10^{3}$ $4.88x10^{2}$ $2.77x10^{3}$
RANGE, 0.1-0.2 70 feet 170 feet 500 feet	$4.27x10^{3}$ $2.20x10^{3}$ $2.84x10^{3}$	$4.37x10^{3}$ $2.52x10^{3}$ $3.12x10^{3}$	$3.12x10^{3}$ $2.37x10^{3}$ $1.55x10^{3}$	$2.55x10^{3}$ $1.62x10^{3}$ $1.94x10^{3}$	$2.60x10^{3}$ $3.20x10^{3}$ $1.38x10^{3}$	$2.78x10^{3}$ $4.84x10^{3}$ $3.03x10^{3}$
RANGE, 0.2-0.3 70 feet 170 feet 500 feet	$4.95x10^{2}$ $3.38x10^{2}$ $2.70x10^{2}$	$8.40x10^{2}$ $5.18x10^{2}$ $4.65x10^{2}$	$5.25x10^{2}$ $3.45x10^{2}$ $1.65x10^{2}$	$2.25x10^{2}$ $1.88x10^{2}$ $1.13x10^{2}$	$4.73x10^{2}$ $2.63x10^{2}$ $1.28x10^{2}$	$4.05x10^{2}$ $3.53x10^{2}$ $3.22x10^{2}$
RANGE, 0.3-0.5 70 feet 170 feet 500 feet	$1.07x10^{2}$ $1.02x10^{2}$ $3.26x10^{1}$	$1.86x10^{2}$ $1.26x10^{2}$ 4.70	$1.26x10^{2}$ $3.26x10^{1}$ $1.86x10^{1}$	9.00 $3.26x10^{1}$ 9.30	$1.21x10^{2}$ $3.70x10^{1}$ 9.00	$9.80x10^{1}$ $1.02x10^{2}$ $1.35x10^{2}$
RANGE, 0.5-1.0 70 feet 170 feet 500 feet	2.04 1.35 1.23	2.12 1.21 1.62	2.13 1.70 0.81	1.81 1.04 0.79	1.45 0.89 0.65	1.30 1.71 1.00
RANGE, 1.0-2.0 70 feet 170 feet 500 feet	0.76 0.37 0.19	0.36 0.20 0.15	0.50 0.37 0.19	0.21 0.24 0.16	0.23 0.20 0.13	0.23 0.42 0.11
RANGE, 2.0-8.0 70 feet 170 feet 500 feet	0.63 0.24 0.11	0.19 0.10 0.06	0.41 0.13 0.08	0.09 0.11 0.07	0.06 0.09 0.05	0.06 0.12 0.03

Table A-III Particle number data for the period 1055-1605, 22 February 1967.

TIME (mid sample)	1230	1240	1250	1300	1310	1320	1330	1340	1350	1400	1410	1420	1430	1440	1450	1500	1510	1520	1530	1540	1550
PARTICLES / CM^3 (DIAMETER-MICRON)																					
TOTAL, 0.002-8 500 feet 170 feet 45 feet	7.64×10^{4}	2.09×10^{5}	1.43×10^{5}	2.56×10^{5}	1.33×10^{5}	3.18×10^{5}	5.44×10^{4}	5.75×10^{4}	2.19×10^{5}	4.18×10^{4}	8.69×10^{4}	1.95×10^{5}	3.37×10^{4}	9.93×10^{4}	1.15×10^{5}	2.11×10^{4}	3.57×10^{4}	2.59×10^{5}	3.70×10^{4}	6.80×10^{4}	1.62×10^{5}
RANGE, 0.002-0.02 500 feet 170 feet 45 feet	3.30×10^{4}	7.38×10^{4}	1.22×10^{3}	1.11×10^{5}	5.41×10^{3}	1.15×10^{5}	8.99×10^{3}	3.26×10^{4}	1.88×10^{5}	1.45×10^{4}	6.91×10^{4}	1.53×10^{5}	1.98×10^{4}	7.92×10^{4}	8.77×10^{4}	2.23×10^{3}	2.39×10^{4}	2.41×10^{5}	1.61×10^{4}	4.74×10^{4}	1.32×10^{5}
RANGE, 0.02-0.03 500 feet 170 feet 45 feet	8.02×10^{2}	7.71×10^{4}	7.96×10^{2}	6.91×10^{4}	8.78×10^{3}	4.62×10^{4}	6.57×10^{3}	4.8×10^{1}	9.33×10^{3}	7.62×10^{3}	2.27×10^{3}	1.25×10^{4}	3.74×10^{3}	8.14×10^{3}	3.26×10^{3}	4.17×10^{3}	3.10×10^{3}	4.30×10^{3}	5.29×10^{3}	2.24×10^{3}	5.17×10^{3}
RANGE, 0.03-0.04 500 feet 170 feet 45 feet	1.10×10^{3}	2.55×10^{4}	1.10×10^{3}	1.99×10^{4}	5.51×10^{3}	1.94×10^{4}	1.99×10^{3}	2.09×10^{3}	4.28×10^{3}	8.28×10^{3}	2.32×10^{3}	1.28×10^{4}	2.37×10^{3}	3.20×10^{3}	7.37×10^{3}	1.03×10^{4}	2.25×10^{3}	1.43×10^{3}	6.60×10^{3}	2.65×10^{3}	9.41×10^{3}
RANGE, 0.04-0.06 500 feet 170 feet 45 feet	2.34×10^{3}	1.18×10^{4}	3.72×10^{4}	7.72×10^{3}	1.64×10^{4}	5.01×10^{4}	3.20×10^{3}	4.64×10^{3}	4.98×10^{3}	5.19×10^{3}	3.66×10^{3}	7.32×10^{3}	2.41×10^{3}	3.12×10^{3}	8.25×10^{3}	1.69×10^{3}	3.44×10^{3}	1.71×10^{3}	4.32×10^{3}	9.42×10^{3}	7.01×10^{3}
RANGE, 0.06-0.08 500 feet 170 feet 45 feet	6.44×10^{3}	7.01×10^{3}	3.75×10^{4}	1.28×10^{4}	3.22×10^{4}	3.73×10^{4}	7.84×10^{3}	4.88×10^{3}	4.94×10^{3}	1.47×10^{3}	4.65×10^{3}	4.70×10^{3}	1.98×10^{3}	2.25×10^{3}	4.14×10^{3}	9.30×10^{2}	1.57×10^{3}	5.80×10^{3}	2.73×10^{3}	4.63×10^{3}	3.70×10^{3}
RANGE, 0.08-0.1 500 feet 170 feet 45 feet	1.97×10^{4}	6.65×10^{3}	3.49×10^{4}	2.07×10^{4}	3.69×10^{4}	2.64×10^{4}	1.27×10^{4}	6.83×10^{3}	4.22×10^{3}	2.65×10^{3}	3.43×10^{3}	2.51×10^{3}	2.04×10^{3}	1.85×10^{3}	2.65×10^{3}	1.23×10^{3}	8.75×10^{2}	3.30×10^{3}	1.44×10^{3}	1.14×10^{3}	3.29×10^{3}
RANGE, 0.1-0.2 500 feet 170 feet 45 feet	1.24×10^{4}	6.44×10^{3}	2.82×10^{4}	1.33×10^{4}	2.58×10^{4}	2.21×10^{4}	1.20×10^{4}	5.94×10^{3}	3.62×10^{3}	1.99×10^{3}	1.35×10^{3}	1.58×10^{3}	1.35×10^{3}	1.36×10^{3}	1.62×10^{3}	4.85×10^{2}	5.34×10^{2}	9.50×10^{2}	4.13×10^{2}	4.67×10^{2}	1.01×10^{3}
RANGE, 0.2-0.3 500 feet 170 feet 45 feet	4.44×10^{2}	6.00×10^{2}	1.70×10^{3}	1.29×10^{3}	2.08×10^{3}	1.44×10^{3}	9.46×10^{2}	3.80×10^{2}	2.39×10^{2}	1.15×10^{2}	6.5×10^{1}	1.23×10^{1}	8.59	1.00×10^{2}	1.60×10^{2}	5.79×10^{1}	3.09×10^{1}	1.08×10^{2}	8.49×10^{1}	6.76	1.47×10^{2}
RANGE, 0.3-0.5 500 feet 170 feet 45 feet	1.68×10^{2}	2.04×10^{2}	2.44×10^{2}	2.76×10^{2}	2.97×10^{2}	2.61×10^{2}	2.60×10^{2}	1.12×10^{2}	4.0×10^{1}	1.27×10^{1}	9.9	1.05	2.04	5.51×10^{1}	1.05×10^{2}	3.00×10^{1}	2.16×10^{1}	3.47×10^{1}	3.59×10^{1}	1.08	8.39×10^{1}
RANGE, 0.5-1.0 500 feet 170 feet 45 feet	2.70	2.67	3.	2.94	2.96	0.83	2.65	2.42	2.32	2.43	2.36	2.66	2.41	2.5	2.76	2.13	2.35	3.11	2.26	2.15	2.57
RANGE, 1.0-2.0 500 feet 170 feet 45 feet	0.24	0.47	0.62	0.36	0.60	0.40	0.37	0.68	0.70	0.27	0.38	0.92	0.33	0.53	0.83	0.24	0.38	0.73	0.27	0.31	0.66
RANGE, 2.0-8.0 500 feet 170 feet 45 feet	0.13	0.42	0.49	0.22	0.42	0.35	0.24	0.54	0.35	0.18	0.29	0.47	0.19	0.36	0.44	0.12	0.26	0.50	0.12	0.21	0.44

Table A-IV Particle number data for the period 1230-1550, 12 July 1967.

TIME (mid sample)	1600	1610	1620	1630	1640	1650	1700	1710	1720	1740	1750	1800	1810	1820	1830	1840	1850	1900	1910	1920	1930
ARTICLES /CM^3 (DIAMETER-MICRON)																					
TOTAL, 0.002-8.0 500 feet 170 feet 45 feet	2.76x10^4	8.15x10^4	1.20x10^5	2.09x10^4	3.97x10^4	2.31x10^5	3.36x10^4	4.35x10^4	4.52x10^4	2.28x10^4	4.29x10^4	4.36x10^4	6.41x10^4	3.39x10^4	4.77x10^4	2.80x10^4	4.21x10^4	4.60x10^4	1.21x10^4	2.73x10^4	4.90x10^4
RANGE, 0.002-0.02 500 feet 170 feet 45 feet	8.93x10^3	5.89x10^4	7.84x10^4	5.19x10^3	2.04x10^4	2.07x10^5	1.84x10^4	2.71x10^4	1.60x10^4	7.67x10^3	1.48x10^4	2.87x10^4	3.54x10^4	1.82x10^4	3.02x10^4	1.57x10^4	2.92x10^4	3.39x10^4	5.88x10^3	1.85x10^4	2.86x10^4
RANGE, 0.02-0.03 500 feet 170 feet 45 feet	6.41x10^4	3.35x10^3	7.39x10^3	7.65x10^4	2.24x10^3	1.43x10^4	9.6 x10^1	4.57x10^3	1.62x10^4	6.4 x10^1	1.60 x10^4	5.64x10^3	1.62x10^4	2.48x10^3	7.80x10^3	4.01x10^2	1.57x10^3	2.26x10^3	1.89x10^3	1.09x10^3	6.69x10^3
RANGE, 0.03-0.04 500 feet 170 feet 45 feet	5.36x10^3	4.96x10^3	6.12x10^3	3.69x10^3	8.98x10^3	1.32x10^2	1.69x10^3	3.97x10^3	6.82x10^3	2.43x10^2	3.20x10^3	3.75x10^3	7.73x10^3	3.58x10^3	2.66x10^3	3.56x10^3	2.22x10^3	2.70x10^3	7.07x10^2	1.98x10^3	5.90x10^3
RANGE, 0.04-0.06 500 feet 170 feet 45 feet	2.67x10^3	5.26x10^3	6.70x10^3	1.64x10^3	4.64x10^3	3.55x10^3	7.18x10^3	4.31x10^3	2.69x10^3	6.36x10^3	2.90x10^3	2.46x10^3	2.08x10^3	3.48x10^3	2.01x10^3	3.61x10^3	3.78x10^3	2.86x10^3	1.54x10^3	2.69x10^3	2.64x10^3
RANGE, 0.06-0.08 500 feet 170 feet 45 feet	2.31x10^3	3.39x10^3	6.81x10^3	1.19x10^3	1.28x10^3	1.53x10^3	4.08x10^3	2.12x10^3	1.36x10^3	6.21x10^3	3.32x10^3	1.33x10^3	1.21x10^3	3.65x10^3	3.11x10^3	2.29x10^3	2.65x10^3	1.63x10^3	8.09x10^2	9.88x10^2	3.12x10^3
RANGE, 0.08-0.1 500 feet 170 feet 45 feet	1.30x10^3	1.78x10^3	2.90x10^3	1.05x10^3	1.33x10^3	2.51x10^3	1.56x10^3	9.77x10^2	1.37x10^2	1.31x10^3	1.79x10^3	1.12x10^3	6.86x10^2	1.56x10^3	8.96x10^2	1.88x10^3	1.55x10^3	1.18x10^3	6.34x10^2	6.44x10^2	1.16x10^3
RANGE, 0.1-0.2 500 feet 170 feet 45 feet	4.10x10^2	7.04x10^2	9.22x10^2	4.73x10^2	6.42x10^2	2.08x10^3	4.78x10^2	4.77x10^2	7.56x10^2	8.39x10^2	9.27x10^2	5.74x10^2	6.81x10^2	7.67x10^2	8.88x10^2	4.39x10^2	1.01x10^3	9.47x10^2	6.00x10^2	1.07x10^3	7.40x10^2
RANGE, 0.2-0.3 500 feet 170 feet 45 feet	1.54x10^2	9.84x10^1	2.07x10^2	2.01x10^1	1.64x10^2	1.62x10^2	6.95x10^1	2.59x10^1	1.29x10^1	2.32x10^1	4.44x10^1	4.83x10^1	6.18x10^1	5.98x10^1	5.75x10^1	7.72x10^1	5.40x10^1	3.32x10^2	1.54x10^1	2.99x10^2	9.26x10^1
RANGE, 0.3-0.5 500 feet 170 feet 45 feet	4.80x10^1	3.00x10^1	1.23x10^2	1.76x10^1	8.99x10^1	7.19	4.2 x10^1	4.55	1.8	2.64x10^1	5.99	3.59x10^1	3.0 x10^1	3.83x10^1	3.59x10^1	3.0 x10^1	6.23x10^1	1.34x10^2	2.4	1.23x10^2	3.59x10^1
RANGE, 0.5-1.0 500 feet 170 feet 45 feet	2.1	2.25	2.59	1.89	2.24	2.36	2.55	2.61	2.81	2.39	2.78	2.69	2.72	2.6	3.48	2.84	3.39	3.18	2.82	2.55	2.94
RANGE, 1.0-2.0 500 feet 170 feet 45 feet	0.26	0.37	0.65	1.5	0.32	0.40	0.28	0.43	0.52	0.23	0.54	0.71	0.39	0.56	0.76	0.34	0.60	0.64	0.3	0.47	0.62
RANGE, 2.0-8.0 500 feet 170 feet 45 feet	0.15	0.25	0.41	0.08	0.27	0.30	0.14	0.30	0.45	0.10	0.39	0.51	0.20	0.39	0.41	0.13	0.30	0.35	0.13	0.29	0.44

Table A-V Particle number data for the period 1600-1930, 12 July 1967.

TIME (mid sample)	1940	1950	2000	2010	2020	2030	2040	2050	2100	2110	2120	2130	2140	2150	2200	2210	2220	2230	2240	2250	2300
PARTICLES /CM^3 (DIAMETER-MICRON)																					
TOTAL, 0.002-8.0																					
500 feet	$2.71x10^4$			$8.83x10^3$			$2.44x10^4$			$6.28x10^4$			$2.12x10^4$			$6.28x10^4$			$3.67x10^4$		
170 feet		$4.26x10^4$			$3.77x10^4$			$6.49x10^4$			$4.26x10^4$			$2.30x10^4$			$4.26x10^4$			$3.70x10^4$	
45 feet			$4.19x10^4$			$4.08x10^4$			$7.33x10^4$			$5.61x10^4$			$4.54x10^4$			$5.61x10^4$			$4.30x10^4$
RANGE, 0.002-0.02																					
500 feet	$9.52x10^3$			$3.28x10^3$			$1.38x10^4$			$2.66x10^4$			$8.85x10^3$			$7.68x10^3$			$3.46x10^3$		
170 feet		$2.44x10^4$			$2.35x10^4$			$3.83x10^4$			$2.50x10^4$			$1.26x10^4$			$6.94x10^3$			$2.51x10^4$	
45 feet			$2.70x10^4$			$2.28x10^4$			$2.81x10^4$			$3.52x10^4$			$2.05x10^4$			$1.58x10^4$			$2.40x10^4$
RANGE, 0.02-0.03																					
500 feet	$5.60x10^3$			$1.99x10^3$			$2.36x10^3$			$3.77x10^3$			$4.01x10^3$			$2.57x10^3$			$6.09x10^3$		
170 feet		$6.26x10^3$			$1.53x10^3$			$8.38x10^3$			$8.30x10^2$			$2132x10^3$			$9.58x10^2$			$9.42x10^2$	
45 feet			$5.38x10^3$			$6.37x10^2$			$1.01x10^4$			$2.60x10^3$			$9.23x10^3$			$1.41x10^4$			$6.46x10^3$
RANGE, 0.03-0.04																					
500 feet	$2.83x10^3$			$9.83x10^2$			$3.66x10^3$			$1.17x10^4$			$2.50x10^3$			$3.64x10^3$			$5.58x10^3$		
170 feet		$9.92x10^2$			$3.19x10^3$			$9.20x10^3$			$3.01x10^3$			$3.57x10^3$			$5.07x10^3$			$2.27x10^3$	
45 feet			$2.76x10^3$			$5.72x10^3$			$1.41x10^4$			$4.62x10^3$			$7.26x10^3$			$9.03x10^3$			$6.11x10^3$
RANGE, 0.04-0.06																					
500 feet	$4.34x10^3$			$7.13x10^2$			$2.16x10^3$			$1.59x10^4$			$2.15x10^3$			$6.55x10^3$			$8.08x10^3$		
170 feet		$4.08x10^3$			$6.01x10^3$			$3.00x10^3$			$5.81x10^3$			$1.80x10^3$			$4.72x10^3$			$2.74x10^3$	
45 feet			$2.73x10^3$			$8.37x10^1$			$1.39x10^4$			$5.80x10^3$			$4.58x10^3$			$3.50x10^3$			$4.09x10^3$
RANGE, 0.06-0.08																					
500 feet	$2.17x10^3$			$3.09x10^2$			$1.42x10^3$			$3.24x10^3$			$1.36x10^3$			$8.83x10^3$			$1.14x10^4$		
170 feet		$3.38x10^3$			$2.36x10^3$			$2.17x10^3$			$4.62x10^3$			$1.30x10^3$			$3.28x10^3$			$2.72x10^3$	
45 feet			$1.41x10^3$			$2.05x10^3$			$4.75x10^3$			$4.60x10^3$			$1.88x10^3$			$1.66x10^3$			$2.32x10^3$
RANGE, 0.08-0.1																					
500 feet	$1.06x10^3$			$8.90x10^2$			$5.76x10^2$			$1.06x10^3$			$1.37x10^3$			$3.78x10^3$			$5.27x10^3$		
170 feet		$1.71x10^3$			$3.88x10^2$			$3.03x10^3$			$2.19x10^3$			$8.38x10^2$			$2.56x10^3$			$2.18x10^3$	
45 feet			$1.17x10^3$			$7.41x10^2$			$1.42x10^3$			$2.32x10^3$			$1.40x10^3$			$1.80x10^3$			$1.33x10^3$
RANGE, 0.1-0.2																					
500 feet	$1.30x10^3$			$5.26x10^2$			$3.08x10^2$			$5.06x10^2$			$8.16x10^2$			$7.01x10^2$			$2.12x10^3$		
170 feet		$1.32x10^3$			$5.73x10^2$			$7.32x10^2$			$8.78x10^2$			$4.36x10^2$			$1.58x10^3$			$1.56x10^3$	
45 feet			$8.35x10^2$			$4.15x10^2$			$6.47x10^2$			$7.86x10^2$			$4.61x10^2$			$1.06x10^3$			$5.96x10^2$
RANGE, 0.2-0.3																					
500 feet	$1.06x10^2$			$9.55x10^1$			$5.79x10^1$			$3.67x10^1$			$7.53x10^1$			$3.01x10^1$			$3.36x10^1$		
170 feet		$3.09x10^2$			$1.56x10^2$			$2.97x10^1$			$1.35x10^2$			$61.8x10^1$			$8.07x10^1$			$2.68x10^1$	
45 feet			$4.44x10^2$			$3.80x10^1$			$1.26x10^2$			$7.14x10^1$			$5.56x10^1$			$5.40x10^1$			$4.44x10^1$
RANGE, 0.3-0.5																					
500 feet	$3.83x10^1$			$4.2\ x10^1$			$3.35x10^1$			$1.80x10^1$			$6.23x10^1$			$1.92x10^1$			6.11		
170 feet		$1.26x10^2$			$3.59x10^1$			4.91			$7.55x10^1$			$3.71x10^1$			5.63			2.64	
45 feet			$1.50x10^2$			$3.59x10^1$			$4.19x10^1$			$5.75x10^1$			$2.52x10^1$			$3.11x10^1$			$2.06x10^1$
RANGE, 0.5-1.0																					
500 feet	2.5			2.5			2.54			2.87			3.			2.79			3.32		
170 feet		3.8			2.35			2.69			3.57			2.74			2.81			2.38	
45 feet			2.49			2.87			3.20			3.17			2.61			2.90			3.
RANGE, 1.0-2.0																					
500 feet	0.31			0.22			0.30			0.43			0.4			0.36			0.43		
170 feet		0.72			0.36			0.53			0.90			0.48			0.55			0.47	
45 feet			0.64			0.49			0.77			0.83			0.63			0.64			0.60
RANGE, 2.0-8.0																					
500 feet	0.17			0.10			0.13			0.16			0.14			0.12			0.14		
170 feet		0.44			0.18			0.50			0.33			0.30			0.29			0.19	
45 feet			0.31			0.24			0.34			0.49			0.41			0.38			0.23

Table A-VI Particle number data for the period 1940-2300, 12 July 1967.

TIME (mid sample)	2310 2320 2330	2340 2350 2400	0010 0020 0030	0040 0050 0100	0110 0120 0130	0140 0150 0200	0210 0220 0230
PARTICLES /CM^3 (DIAMETER-MICRON)							
TOTAL, 0.002-8.0							
500 feet	1.44×10^{4}	2.30×10^{4}	3.99×10^{4}	3.30×10^{4}	1.40×10^{4}	1.51×10^{4}	1.74×10^{4}
170 feet	3.14×10^{4}	3.87×10^{4}	5.93×10^{4}	4.06×10^{4}	3.78×10^{4}	3.38×10^{4}	2.75×10^{4}
45 feet	5.81×10^{4}	6.43×10^{4}	6.36×10^{4}	4.92×10^{4}	5.09×10^{4}	4.21×10^{4}	3.16×10^{4}
RANGE, 0.002-0.02							
500 feet	5.47×10^{3}	8.64×10^{3}	3.07×10^{4}	1.06×10^{4}	3.30×10^{3}	2.66×10^{3}	7.64×10^{3}
170 feet	1.93×10^{4}	1.54×10^{4}	2.81×10^{4}	1.86×10^{4}	2.14×10^{4}	1.69×10^{4}	1.37×10^{4}
45 feet	3.39×10^{4}	2.73×10^{4}	3.27×10^{4}	2.58×10^{4}	2.86×10^{4}	2.34×10^{4}	1.88×10^{4}
RANGE, 0.02-0.03							
500 feet	2.68×10^{3}	2.92×10^{3}	2.65×10^{3}	1.36×10^{3}	3.37×10^{3}	3.56×10^{3}	2.73×10^{3}
170 feet	3.19×10^{3}	1.01×10^{4}	2.32×10^{3}	9.58×10^{2}	2.56×10^{3}	1.60×10^{3}	1.52×10^{3}
45 feet	9.01×10^{3}	1.11×10^{3}	2.52×10^{3}	4.78×10^{3}	5.41×10^{3}	5.89×10^{3}	3.18×10^{3}
RANGE, 0.03-0.04							
500 feet	2.15×10^{3}	3.39×10^{3}	7.73×10^{1}	6.07×10^{2}	5.52×10^{2}	2.97×10^{3}	1.71×10^{3}
170 feet	2.98×10^{3}	6.42×10^{3}	4.11×10^{3}	3.31×10^{3}	7.16×10^{2}	4.71×10^{3}	3.25×10^{3}
45 feet	7.12×10^{3}	9.13×10^{3}	4.07×10^{3}	2.64×10^{3}	4.79×10^{3}	3.69×10^{3}	3.23×10^{3}
RANGE, 0.04-0.06							
500 feet	1.51×10^{3}	4.02×10^{3}	7.86×10^{3}	6.44×10^{3}	2.54×10^{3}	2.58×10^{3}	2.30×10^{3}
170 feet	2.63×10^{3}	6.78×10^{3}	1.04×10^{4}	6.39×10^{3}	5.18×10^{3}	5.40×10^{3}	4.07×10^{3}
45 feet	3.77×10^{3}	1.21×10^{4}	9.11×10^{3}	1.95×10^{3}	4.01×10^{3}	4.52×10^{3}	3.78×10^{3}
RANGE, 0.06-0.08							
500 feet	6.88×10^{2}	2.85×10^{3}	1.12×10^{4}	6.72×10^{3}	1.38×10^{3}	1.52×10^{3}	1.58×10^{3}
170 feet	1.71×10^{3}	5.38×10^{3}	6.79×10^{3}	3.12×10^{3}	3.47×10^{3}	2.33×10^{3}	2.70×10^{3}
45 feet	2.25×10^{3}	7.20×10^{3}	7.49×10^{3}	7.84×10^{3}	4.11×10^{3}	2.35×10^{3}	1.85×10^{3}
RANGE, 0.08-0.1							
500 feet	9.48×10^{2}	6.81×10^{2}	5.13×10^{3}	5.34×10^{3}	1.70×10^{3}	1.12×10^{3}	7.96×10^{2}
170 feet	1.31×10^{3}	3.22×10^{3}	4.49×10^{3}	4.78×10^{3}	3.01×10^{3}	2.28×10^{3}	1.36×10^{3}
45 feet	1.21×10^{3}	4.62×10^{3}	4.47×10^{3}	4.22×10^{3}	2.33×10^{3}	1.25×10^{3}	1.26×10^{3}
RANGE, 0.1-0.2							
500 feet	1.10×10^{3}	4.19×10^{2}	2.18×10^{3}	2.60×10^{3}	1.12×10^{3}	6.32×10^{2}	5.29×10^{2}
170 feet	3.28×10^{2}	1.59×10^{3}	2.96×10^{3}	3.21×10^{3}	1.37×10^{3}	4.46×10^{2}	7.84×10^{2}
45 feet	6.31×10^{2}	2.88×10^{3}	3.14×10^{3}	1.95×10^{3}	1.50×10^{3}	6.73×10^{2}	7.88×10^{2}
RANGE, 0.2-0.3							
500 feet	3.40×10^{1}	3.20×10^{1}	5.52×10^{1}	9.46×10^{1}	6.85×10^{1}	3.38×10^{1}	2.90×10^{1}
170 feet	5.79	3.53×10^{1}	1.01×10^{2}	1.60×10^{2}	7.08×10^{1}	5.21×10^{1}	3.31×10^{1}
45 feet	7.97×10^{1}	9.86×10^{1}	1.19×10^{2}	1.07×10^{2}	9.73×10^{1}	8.32×10^{1}	5.06×10^{1}
RANGE, 0.3-0.5							
500 feet	7.31	3.59×10^{1}	5.63	1.62×10^{1}	1.38×10^{1}	9.82	1.05×10^{1}
170 feet	0.84	6.23	5.75	2.66×10^{1}	1.62×10^{1}	1.15×10^{1}	1.26×10^{1}
45 feet	4.67×10^{1}	8.87	1.16×10^{1}	2.22×10^{1}	1.37×10^{1}	1.26	1.29×10^{1}
RANGE, 0.5-1.0							
500 feet	2.80	5.51	3.28	3.17	2.7	2.30	2.38
170 feet	2.93	2.75	3.48	3.07	2.52	2.44	2.60
45 feet	3.03	3.54	3.01	3.07	2.95	2.92	2.52
RANGE, 1.0-2.0							
500 feet	0.31	0.40	0.47	0.39	0.29	0.24	0.24
170 feet	0.49	0.57	0.70	0.55	0.40	0.38	0.37
45 feet	0.64	0.79	0.65	0.57	0.47	0.86	0.34
RANGE, 2.0-8.0							
500 feet	0.10	0.13	0.15	0.15	0.13	0.11	0.10
170 feet	0.18	0.21	0.33	0.30	0.20	0.18	0.40
45 feet	0.23	0.36	0.32	0.33	0.21	0.18	0.14

Table A-VII Particle number data for the periods 2310-2400, 12 July 1967 and 0010-0230, 13 July 1967.

TIME (mid sample)	0240	0250	0300	0310	0320	0330	0340	0350	0400	0410	0420	0430	0440	0450	0500	0510	0520	0530	0540	0550
PARTICLES /CM^3 (DIAMETER-MICRON)																				
TOTAL, 0.002-8.0 500 feet 170 feet 45 feet	$1.26x10^4$	$3.25x10^4$	$3.99x10^4$	$1.16x10^4$	$2.46x10^4$	$4.45x10^4$	$6.89x10^3$	$1.27x10^4$	$2.16x10^4$	$3.75x10^3$	$1.04x10^4$	$2.10x10^4$	$4.12x10^3$	$6.36x10^3$	$2.75x10^4$	$1.63x10^4$	$1.17x10^4$	$3.98x10^4$	$2.65x10^4$	$2.07x10^4$
RANGE, 0.002-0.02 500 feet 170 feet 45 feet	$1.98x10^3$	$1.37x10^4$	$2.07x10^4$	$3.41x10^3$	$4.45x10^3$	$2.34x10^4$	$1.06x10^3$	$2.98x10^3$	$1.18x10^4$	$2.47x10^2$	$4.71x10^3$	$9.00x10^3$	$1.19x10^3$	$2.15x10^3$	$9.30x10^3$	$9.56x10^3$	$4.30x10^3$	$3.04x10^4$	$1.27x10^4$	$8.37x10^3$
RANGE, 0.02-0.03 500 feet 170 feet 45 feet	$2.41x10^3$	$4.22x10^3$	$3.90x10^3$	$1.69x10^3$	$6.87x10^3$	$8.20x10^3$	$6.25x10^2$	$4.34x10^3$	$2.07x10^3$	$6.89x10^2$	$1.85x10^3$	$6.69x10^2$	$7.13x10^2$	$2.72x10^2$	$1.21x10^4$	$2.49x10^3$	$2.75x10^3$	$5.57x10^2$	$4.86x10^3$	$2.11x10^3$
RANGE, 0.03-0.04 500 feet 170 feet 45 feet	$2.29x10^3$	$4.85x10^3$	$4.95x10^3$	$1.60x10^3$	$4.30x10^3$	$7.15x10^3$	$1.06x10^3$	$1.80x10^3$	$3.28x10^3$	$5.63x10^2$	$1.14x10^3$	$2.29x10^3$	$5.02x10^2$	$1.12x10^3$	$2.94x10^3$	$1.27x10^3$	$1.65x10^3$	$1.54x10^3$	$3.82x10^3$	$3.73x10^3$
RANGE, 0.04-0.06 500 feet 170 feet 45 feet	$2.83x10^3$	$5.22x10^3$	$4.79x10^3$	$2.18x10^3$	$4.38x10^3$	$8.49x10^3$	$1.76x10^3$	$1.47x10^3$	$1.93x10^3$	$8.12x10^2$	$9.90x10^2$	$6.03x10^3$	$4.60x10^2$	$1.04x10^3$	$1.40x10^3$	$1.15x10^3$	$1.04x10^3$	$1.29x10^3$	$2.97x10^3$	$2.90x10^3$
RANGE, 0.06-0.08 500 feet 170 feet 45 feet	$1.60x10^3$	$2.00x10^3$	$2.76x10^3$	$1.37x10^3$	$2.15x10^3$	$2.29x10^3$	$1.41x10^3$	$9.88x10^2$	$1.13x10^3$	$5.29x10^2$	$5.86x10^2$	$1.78x10^3$	$3.89x10^2$	$5.48x10^2$	$5.23x10^2$	$7.14x10^2$	$2.36x10^2$	$1.94x10^3$	$1.12x10^3$	$2.04x10^3$
RANGE, 0.08-0.1 500 feet 170 feet 45 feet	$8.12x10^2$	$1.46x10^3$	$1.69x10^3$	$7.59x10^2$	$1.56x10^3$	$1.83x10^3$	$6.65x10^2$	$6.28x10^2$	$8.22x10^2$	$4.66x10^2$	$5.97x10^2$	$7.07x10^2$	$4.77x10^2$	$5.87x10^2$	$5.39x10^2$	$5.29x10^2$	$4.50x10^2$	$2.70x10^3$	$5.76x10^2$	$1.00x10^3$
RANGE, 0.1-0.2 500 feet 170 feet 45 feet	$6.38x10^2$	$9.66x10^2$	$1.09x10^3$	$5.45x10^2$	$8.16x10^2$	$1.45x10^3$	$5.29x10^2$	$4.60x10^2$	$4.70x10^2$	$3.90x10^2$	$4.55x10^2$	$4.32x10^2$	$3.49x10^2$	$5.77x10^2$	$6.00x10^2$	$4.84x10^2$	$1.06x10^3$	$1.33x10^3$	$4.05x10^2$	$6.08x10^2$
RANGE, 0.2-0.3 500 feet 170 feet 45 feet	$4.23x10^1$	$7.82x10^1$	$7.14x10^1$	$3.22x10^1$	$5.5\ x10^1$	$5.19x10^1$	$2.84x10^1$	$2.37x10^1$	$3.16x10^1$	$4.19x10^1$	$3.9\ x10^1$	$3.19x10^1$	$2.78x10^1$	$4.63x10^1$	$3.37x10^1$	$4.23x10^1$	$2.06x10^2$	$5.39x10^1$	$3.49x10^1$	$4.65x10^1$
RANGE, 0.3-0.5 500 feet 170 feet 45 feet	$1.09x10^1$	$1.40x10^1$	$1.49x10^1$	$1.09x10^1$	$1.44x10^1$	$1.69x10^1$	$1.20x10^1$	$1.10x10^1$	$1.08x10^1$	7.31	$1.02x10^1$	$1.14x10^1$	$1.10x10^1$	$1.56x10^1$	$1.22x10^1$	$1.44x10^1$	$1.25x10^1$	$1.43x10^1$	6.47	6.35
RANGE, 0.5-1.0 500 feet 170 feet 45 feet	2.46	2.72	2.87	2.50	2.72	2.10	2.41	2.43	2.42	2.34	2.40	2.41	1.88	1.93	2.1	1.96	2.00	3.22	1.83	2.21
RANGE, 1.0-2.0 500 feet 170 feet 45 feet	0.24	0.41	0.44	0.23	0.36	0.28	0.18	0.22	2.37	0.16	0.21	0.26	0.11	0.14	0.19	0.16	0.23	0.37	0.18	0.23
RANGE, 2.0-8.0 500 feet 170 feet 45 feet	0.09	0.16	0.14	0.08	0.14	0.13	0.07	0.11	0.11	0.07	0.12	0.12	0.05	0.07	0.10	0.09	0.07	0.03	0.09	0.10

Table A-VIII Particle number data for the period 0240-0550, 13 July 1967.

TIME (mid sample)	0610	0620	0630—0700	0710	0720	0730—0740	0750	0810	0820—0840	0850	0900	0910	0920	0930	0940	0950	1000	1010
PARTICLES / CM^3 (DIAMETER-MICRON)																		
TOTAL, 0.002-8.0																		
500 feet					2.02x10^{4}		3.03x10^{4}			4.52x10^{4}			9.32x10^{4}			6.15x10^{4}		
170 feet		2.69x10^{4}									2.04x10^{5}			1.06x10^{5}			6.60x10^{4}	
45 feet	3.52x10^{4}			5.70x10^{4}				7.20x10^{4}				1.87x10^{5}			1.41x10^{5}			9.81x10^{4}
RANGE, 0.002-0.02																		
500 feet					1.21x10^{4}		1.43x10^{4}			1.33x10^{4}			2.81x10^{4}			3.03x10^{4}		
170 feet		1.29x10^{4}									9.05x10^{4}			5.21x10^{4}			3.68x10^{4}	
45 feet	1.92x10^{4}			3.38x10^{4}				3.68x10^{4}				6.29x10^{4}			8.90x10^{4}			4.66x10^{4}
RANGE, 0.02-0.03																		
500 feet					2.89x10^{3}		8.56x10^{3}			1.37x10^{4}			3.65x10^{4}			1.53x10^{4}		
170 feet		2.93x10^{3}									7.35x10^{4}			2.36x10^{4}			9.90x10^{3}	
45 feet	4.81x10^{3}			1.13x10^{4}				7.48x10^{3}				6.86x10^{4}			1.91x10^{4}			2.85x10^{4}
RANGE, 0.03-0.04																		
500 feet					1.77x10^{3}		2.85x10^{3}			7.05x10^{3}			1.58x10^{4}			6.79x10^{3}		
170 feet		2.09x10^{3}									2.09x10^{4}			1.30x10^{4}			6.08x10^{3}	
45 feet	3.81x10^{3}			4.18x10^{3}				5.83x10^{3}				3.10x10^{4}			1.10x10^{4}			1.19x10^{4}
RANGE, 0.04-0.06																		
500 feet					1.43x10^{3}		2.12x10^{3}			4.31x10^{3}			8.43x10^{3}			4.99x10^{3}		
170 feet		3.94x10^{3}									1.09x10^{4}			8.73x10^{3}			5.53x10^{3}	
45 feet	3.97x10^{3}			2.58x10^{3}				1.32x10^{4}				1.56x10^{4}			1.04x10^{4}			6.79x10^{3}
RANGE, 0.06-0.08																		
500 feet					6.69x10^{2}		1.32x10^{3}			2.20x10^{3}			2.39x10^{3}			1.90x10^{3}		
170 feet		3.41x10^{3}									4.54x10^{3}			5.12x10^{3}			2.38x10^{3}	
45 feet	1.93x10^{3}			1.01x10^{3}				2.49x10^{3}				4.81x10^{3}			7.31x10^{3}			2.41x10^{3}
RANGE, 0.08-0.1																		
500 feet					5.97x10^{2}		7.31x10^{2}			1.10x10^{3}			1.34x10^{3}			1.34x10^{3}		
170 feet		9.11x10^{2}									1.94x10^{3}			1.83x10^{3}			2.17x10^{3}	
45 feet	9.37x10^{2}			1.97x10^{3}				3.80x10^{3}				2.91x10^{3}			2.71x10^{3}			1.02x10^{3}
RANGE, 0.1-0.2																		
500 feet					5.41x10^{2}		4.14x10^{2}			1.37x10^{3}			6.26x10^{2}			7.54x10^{2}		
170 feet		6.52x10^{2}									1.62x10^{3}			1.31x10^{3}			9.76x10^{2}	
45 feet	4.75x10^{2}			1.71x10^{3}				2.30x10^{3}				9.11x10^{2}			1.76x10^{3}			7.67x10^{2}
RANGE, 0.2-0.3																		
500 feet					9.26x10^{1}		2.24x10^{1}			7.72x10^{1}			4.0 x10^{1}			1.31x10^{1}		
170 feet		2.2 x10^{1}									1.93x10^{2}			5.58x10^{1}			6.43x10^{1}	
45 feet	2.59x10^{1}			1.87x10^{2}				8.30x10^{1}				9.07x10^{1}			1.04x10^{2}			6.93x10^{1}
RANGE, 0.3-0.5																		
500 feet					6.23x10^{1}		5.15			1.92x10^{1}			9.6			8.4		
170 feet		0.6									2.64x10^{2}			1.32			1.38x10^{1}	
45 feet	2.64			1.02x10^{2}				1.37x10^{1}				8.75			2.25x10^{1}			3.75x10^{1}
RANGE, 0.5-1.0																		
500 feet					2.00		2.07			2.35			2.03			2.57		
170 feet		2.44									2.14			2.25			2.64	
45 feet	2.45			4.14				3.68				3.57			3.30			3.61
RANGE, 1.0-2.0																		
500 feet					0.18		0.27			0.37			0.28			0.22		
170 feet		0.24									0.42			0.37			0.40	
45 feet	0.26			0.99				1.84				1.90			1.46			1.08
RANGE, 2.0-8.0																		
500 feet					0.08		0.13			0.15			0.16			0.10		
170 feet		0.12									0.12			0.31			0.16	
45 feet	0.14			0.39				0.57				0.68			0.58			0.44

Table A-IX Particle number data for the period 0610-1010, 13 July 1967.

TIME (mid sample)	1020	1030	1040	1050	1100	1110	1120	1130	1140	1150	1200—1450	1500	1510	1520	1530	1540	1550	1600	1610	1620
PARTICLES / CM^3 (DIAMETER-MICRON)																				
TOTAL, 0.002-8.0 500 feet 170 feet 45 feet	$4.07x10^4$	$1.85x10^3$	$1.60x10^5$	$2.41x10^4$	$2.92x10^4$	$1.02x10^5$	$4.32x10^4$	$6.21x10^4$	$9.55x10^4$	$2.42x10^4$		$1.01x10^5$	$1.74x10^5$	$3.60x10^4$	$5.24x10^4$	$2.06x10^4$	$2.96x10^4$	$7.06x10^4$	$1.20x10^5$	$3.02x10^4$
RANGE, 0.002-0.02 500 feet 170 feet 45 feet	$1.85x10^4$	$1.59x10^4$	$1.03x10^5$	$8.78x10^3$	$8.49x10^3$	$6.72x10^4$	$2.36x10^4$	$3.08x10^4$	$6.21x10^4$	$9.39x10^3$		$8.64x10^4$	$1.36x10^5$	$1.86x10^4$	$3.57x10^4$	$1.60x10^5$	$1.19x10^4$	$4.56x10^4$	$8.57x10^4$	$1.53x10^4$
RANGE, 0.02-0.03 500 feet 170 feet 45 feet	$1.15x10^4$	$1.56x10^4$	$9.55x10^3$	$3.85x10^3$	$7.87x10^3$	$1.03x10^4$	$9.30x10^3$	$1.29x10^4$	$1.37x10^4$	$5.90x10^3$		$3.99x10^3$	$1.89x10^4$	$8.82x10^3$	$1.44x10^3$	$2.12x10^4$	$6.91x10^3$	$6.23x10^3$	$1.46x10^4$	$6.96x10^3$
RANGE, 0.03-0.04 500 feet 170 feet 45 feet	$5.57x10^3$	$5.73x10^3$	$2.07x10^4$	$3.17x10^3$	$4.21x10^3$	$7.81x10^3$	$3.26x10^3$	$8.27x10^3$	$5.12x10^3$	$2.33x10^3$		$3.03x10^3$	$8.53x10^3$	$2.54x10^3$	$2.20x10^3$	$8.03x10^3$	$4.74x10^3$	$9.26x10^3$	$8.97x10^3$	$3.70x10^3$
RANGE, 0.04-0.06 500 feet 170 feet 45 feet	$3.29x10^3$	$3.25x10^3$	$2.02x10^4$	$4.39x10^3$	$2.54x10^3$	$7.16x10^3$	$2.53x10^3$	$4.68x10^3$	$4.17x10^3$	$3.26x10^3$		$4.08x10^3$	$5.96x10^3$	$2.25x10^3$	$8.89x10^3$	$5.12x10^3$	$3.08x10^3$	$6.16x10^3$	$6.41x10^3$	$2.20x10^3$
RANGE, 0.06-0.08 500 feet 170 feet 45 feet	$7.84x10^2$	$2.15x10^3$	$7.93x10^3$	$2.45x10^3$	$3.88x10^3$	$6.50x10^3$	$2.85x10^3$	$2.31x10^3$	$5.18x10^3$	$1.84x10^3$		$2.24x10^3$	$1.72x10^3$	$1.17x10^3$	$2.56x10^3$	$1.06x10^3$	$1.56x10^3$	$1.63x10^3$	$2.07x10^3$	$6.18x10^2$
RANGE, 0.08-0.1 500 feet 170 feet 45 feet	$5.08x10^2$	$1.03x10^3$	$3.91x10^3$	$8.33x10^2$	$1.23x10^3$	$1.29x10^3$	$9.64x10^2$	$1.77x10^3$	$1.90x10^3$	$9.16x10^2$		$5.60x10^2$	$1.66x10^3$	$7.59x10^2$	$9.32x10^2$	$1.44x10^3$	$1.07x10^3$	$9.32x10^2$	$1.34x10^3$	$8.80x10^2$
RANGE, 0.1-0.2 500 feet 170 feet 45 feet	$4.15x10^2$	$5.32x10^2$	$2.40x10^3$	$5.08x10^2$	$8.60x10^2$	$1.30x10^3$	$6.82x10^2$	$1.16x10^3$	$2.98x10^3$	$7.39x10^2$		$6.36x10^2$	$1.00x10^3$	$4.23x10^2$	$6.29x10^2$	$6.78x10^2$	$3.54x10^2$	$6.11x10^2$	$6.09x10^2$	$3.77x10^2$
RANGE, 0.2-0.3 500 feet 170 feet 45 feet	$3.05x10^1$	$6.14x10^1$	$6.14x10^1$	$5.6\ x10^1$	$5.31x10^1$	$1.04x10^2$	$1.56x10^1$	$2.04x10^2$	$2.90x10^2$	$4.1\ x10^1$		$6.7\ x10^1$	$4.7\ x10^1$	$1.12x10^3$	$8.8\ x10^1$	$7.2\ x10^1$	8.	$2.0\ x10^1$	$6.3\ x10^1$	$1.1\ x10^1$
RANGE, 0.3-0.5 500 feet 170 feet 45 feet	$1.62x10^1$	$3.01x10^1$	$2.9\ x10^1$	$2.04x10^1$	$1.68x10^1$	3.7	5.29	$1.56x10^1$	$6.89x10^1$	$1.5\ x10^1$		$2.3\ x10^1$	$4.1\ x10^1$	$2.94x10^2$	$2.5\ x10^1$	$2.9\ x10^1$	5.	$1.4\ x10^1$	$2.3\ x10^1$	8.
RANGE, 0.5-1.0 500 feet 170 feet 45 feet	2.18	2.36	3.60	1.91	2.19	2.62	1.96	2.2	3.80	2.12		2.26	2.91	2.10	2.38	2.53	2.06	2.14	2.19	2.10
RANGE, 1.0-2.0 500 feet 170 feet 45 feet	0.11	0.24	1.33	0.11	0.32	0.79	0.16	0.30	1.09	0.21		0.41	0.81	0.21	0.45	0.56	0.20	0.33	0.73	0.26
RANGE, 2.0-8.0 500 feet 170 feet 45 feet	0.07	0.14	0.30	0.08	0.21	0.35	0.10	0.22	0.38	0.12		0.32	0.42	0.14	0.31	0.35	0.14	0.24	0.36	0.19

Table A-X Particle number data for the periods 1020-1150 and 1500-1620, 13 July 1967.

TIME (mid sample)	1455 1505	1515 1525 1535	1545 1555 1605	1615 1625 1635	1645 1655 1705	1715 1725 1735	1745 1755 1805
PARTICLES / CM^3 (diameter-micron)							
TOTAL. 0.002-8.0							
500 feet		6.24×10^{4}	2.61×10^{4}	6.20×10^{4}	2.64×10^{4}	4.54×10^{4}	2.05×10^{4}
170 feet	1.57×10^{5}	6.49×10^{4}	5.36×10^{4}	5.27×10^{4}	3.86×10^{4}	4.57×10^{4}	5.42×10^{4}
45 feet	1.92×10^{5}	1.31×10^{5}	8.91×10^{4}	9.09×10^{4}	1.13×10^{5}	9.08×10^{4}	1.02×10^{5}
RANGE, 0.002-0.02							
500 feet		5.39×10^{3}	1.03×10^{4}	3.43×10^{4}	1.20×10^{4}	1.79×10^{4}	1.30×10^{4}
170 feet	7.38×10^{3}	4.68×10^{4}	3.43×10^{4}	3.66×10^{4}	2.15×10^{4}	2.77×10^{4}	3.30×10^{4}
45 feet	1.22×10^{4}	1.01×10^{5}	6.38×10^{4}	6.58×10^{4}	7.67×10^{4}	6.78×10^{4}	8.09×10^{4}
RANGE, 0.02-0.03							
500 feet		6.41×10^{2}	1.44×10^{3}	3.13×10^{3}	2.57×10^{3}	7.53×10^{3}	5.61×10^{3}
170 feet	1.60×10^{4}	2.56×10^{2}	6.87×10^{3}	1.12×10^{3}	1.61×10^{4}	1.92×10^{3}	5.43×10^{3}
45 feet	2.63×10^{4}	6.15×10^{3}	6.37×10^{3}	1.03×10^{4}	1.99×10^{4}	4.46×10^{3}	5.25×10^{3}
RANGE, 0.03-0.04							
500 feet		2.21×10^{2}	2.43×10^{3}	4.09×10^{3}	2.43×10^{3}	6.85×10^{3}	4.31×10^{3}
170 feet	1.65×10^{4}	4.41×10^{3}	3.42×10^{3}	2.54×10^{3}	5.07×10^{3}	4.96×10^{3}	3.42×10^{3}
45 feet	1.29×10^{4}	7.64×10^{3}	4.84×10^{3}	1.76×10^{3}	6.38×10^{3}	5.17×10^{3}	3.30×10^{3}
RANGE, 0.04-0.06							
500 feet		6.24×10^{2}	6.09×10^{3}	1.01×10^{4}	3.59×10^{3}	7.88×10^{3}	2.97×10^{3}
170 feet	2.88×10^{4}	5.46×10^{3}	3.04×10^{3}	5.30×10^{3}	3.51×10^{3}	5.53×10^{3}	5.46×10^{3}
45 feet	8.58×10^{4}	7.24×10^{3}	5.45×10^{3}	5.22×10^{3}	3.97×10^{3}	6.85×10^{3}	4.36×10^{3}
RANGE, 0.06-0.08							
500 feet		2.42×10^{3}	1.98×10^{3}	5.86×10^{2}	2.55×10^{3}	2.52×10^{3}	1.85×10^{3}
170 feet	3.45×10^{4}	1.59×10^{3}	2.42×10^{3}	3.70×10^{3}	2.17×10^{3}	2.09×10^{3}	3.06×10^{3}
45 feet	1.41×10^{4}	2.93×10^{3}	4.02×10^{3}	3.95×10^{3}	2.74×10^{3}	2.68×10^{3}	3.89×10^{3}
RANGE, 0.08-0.1							
500 feet		2.93×10^{3}	2.04×10^{3}	2.49×10^{3}	1.52×10^{3}	1.23×10^{3}	1.26×10^{3}
170 feet	2.48×10^{4}	1.92×10^{3}	1.81×10^{3}	1.55×10^{3}	1.55×10^{3}	1.73×10^{3}	1.89×10^{3}
45 feet	1.86×10^{4}	5.59×10^{3}	3.12×10^{3}	1.68×10^{3}	1.47×10^{3}	1.83×10^{3}	1.94×10^{3}
RANGE, 0.1-0.2							
500 feet		7.88×10^{3}	1.49×10^{3}	1.75×10^{3}	1.54×10^{3}	1.29×10^{3}	1.28×10^{3}
170 feet	2.71×10^{4}	3.78×10^{3}	1.49×10^{3}	1.61×10^{3}	1.34×10^{3}	1.54×10^{3}	1.70×10^{3}
45 feet	2.02×10^{4}	3.18×10^{2}	1.16×10^{3}	1.77×10^{3}	1.25×10^{3}	1.67×10^{3}	1.80×10^{3}
RANGE, 0.2-0.3							
500 feet		4.10×10^{2}	2.03×10^{2}	1.83×10^{2}	1.16×10^{2}	1.68×10^{2}	1.54×10^{2}
170 feet	1.52×10^{3}	4.92×10^{2}	1.76×10^{2}	1.87×10^{2}	1.27×10^{2}	1.54×10^{2}	2.22×10^{2}
45 feet	1.64×10^{3}	3.18×10^{2}	2.32×10^{2}	2.41×10^{2}	1.35×10^{2}	1.93×10^{2}	2.70×10^{2}
RANGE, 0.3-0.5							
500 feet		3.9×10^{1}	1.68×10^{2}	9.6×10^{1}	1.20×10^{2}	5.0×10^{1}	8.4×10^{1}
170 feet	1.84×10^{2}	2.22×10^{2}	9.6×10^{1}	9.3×10^{1}	5.4×10^{1}	7.2×10^{1}	6.6×10^{1}
45 feet	5.08×10^{2}	1.68×10^{2}	1.20×10^{2}	1.38×10^{2}	6.0×10^{1}	8.4×10^{1}	1.44×10^{2}
RANGE, 0.5-1.0							
500 feet		2.90	2.94	3.05	2.94	2.95	2.85×10^{3}
170 feet	3.47	2.91	3.02	3.00	3.07	3.02	3.07
45 feet	3.25	3.1	3.18	3.21	2.94	3.24	3.30
RANGE, 1.0-2.0							
500 feet		0.15	0.50	0.56	0.46	0.47	0.40
170 feet	0.75	1.32	0.63	0.63	0.58	0.66	0.70
45 feet	0.72	0.8	0.69	0.82	0.58	0.81	0.88
RANGE, 2.0-8.0							
500 feet		0.19	0.22	0.23	0.16	0.19	0.16
170 feet	0.36	0.36	0.32	0.31	0.26	0.35	0.36
45 feet	0.31	0.42	0.32	0.36	0.29	0.35	0.38

Table A-XI Particle number data for the period 1455-1805, 19 July 1967.

TIME (mid sample)	1815 1825 1835	1845 1855 1905	1915 1925 1935	1945 1955 2005	2015 2025 2035	2045 2055 2105	2115 2125 2135
PARTICLES / CM^3 (diameter-micron)							
TOTAL, 0.002-8.0 500 feet 170 feet 45 feet	1.01×10^{4} 3.35×10^{4} 8.71×10^{4}	3.07×10^{4} 4.24×10^{4} 5.69×10^{4}	1.90×10^{4} 7.72×10^{4} 1.04×10^{5}	1.83×10^{5} 1.04×10^{5} 1.48×10^{5}	4.77×10^{4} 7.90×10^{4} 1.04×10^{5}	8.32×10^{4} 6.70×10^{4} 1.12×10^{5}	7.02×10^{4} 6.31×10^{4} 9.29×10^{4}
RANGE, 0.002-0.02 500 feet 170 feet 45 feet	7.41×10^{2} 1.83×10^{4} 5.89×10^{4}	1.33×10^{4} 1.86×10^{4} 4.02×10^{4}	3.06×10^{3} 5.44×10^{4} 6.62×10^{4}	7.24×10^{4} 5.30×10^{4} 9.34×10^{4}	9.89×10^{2} 3.38×10^{4} 6.90×10^{4}	3.02×10^{4} 3.19×10^{4} 7.19×10^{4}	3.52×10^{4} 5.67×10^{4} 6.45×10^{4}
RANGE, 0.02-0.03 500 feet 170 feet 45 feet	6.41×10^{2} 3.51×10^{3} 9.23×10^{3}	4.17×10^{3} 1.07×10^{4} 4.78×10^{2}	5.61×10^{2} 1.59×10^{2} 1.13×10^{4}	5.96×10^{4} 1.36×10^{4} 1.88×10^{4}	2.41×10^{3} 7.51×10^{3} 1.11×10^{4}	3.00×10^{4} 8.94×10^{3} 9.39×10^{3}	4.01×10^{3} 1.13×10^{3} 2.07×10^{3}
RANGE, 0.03-0.04 500 feet 170 feet 45 feet	1.44×10^{3} 3.09×10^{3} 5.83×10^{3}	3.65×10^{3} 4.52×10^{3} 5.28×10^{3}	5.52×10^{2} 3.75×10^{3} 9.13×10^{3}	1.82×10^{4} 1.04×10^{4} 1.32×10^{4}	1.24×10^{4} 6.95×10^{3} 6.49×10^{3}	9.83×10^{3} 6.61×10^{3} 9.46×10^{3}	4.64×10^{3} 1.23×10^{3} 6.60×10^{3}
RANGE, 0.04-0.06 500 feet 170 feet 45 feet	2.42×10^{3} 2.26×10^{3} 2.88×10^{3}	3.90×10^{3} 3.35×10^{3} 4.20×10^{3}	2.97×10^{3} 7.09×10^{3} 7.16×10^{3}	1.61×10^{4} 1.30×10^{4} 8.33×10^{3}	1.32×10^{4} 7.72×10^{3} 6.93×10^{3}	5.89×10^{3} 7.01×10^{3} 8.02×10^{3}	9.28×10^{3} 1.68×10^{3} 1.02×10^{4}
RANGE, 0.06-0.08 500 feet 170 feet 45 feet	1.66×10^{3} 1.15×10^{3} 6.72×10^{3}	2.42×10^{3} 2.23×10^{3} 1.78×10^{3}	8.80×10^{3} 1.47×10^{3} 5.61×10^{3}	9.75×10^{3} 1.02×10^{3} 5.23×10^{3}	1.03×10^{4} 1.17×10^{4} 4.08×10^{3}	3.04×10^{3} 5.61×10^{3} 5.16×10^{3}	8.92×10^{3} 1.03×10^{3} 3.76×10^{3}
RANGE, 0.08-0.1 500 feet 170 feet 45 feet	1.62×10^{3} 1.89×10^{3} 1.66×10^{3}	1.73×10^{3} 1.31×10^{3} 1.52×10^{3}	1.10×10^{3} 5.45×10^{3} 2.41×10^{3}	3.36×10^{3} 5.03×10^{3} 5.13×10^{3}	5.03×10^{3} 6.18×10^{3} 2.72×10^{3}	2.15×10^{3} 3.77×10^{3} 4.09×10^{3}	4.66×10^{3} 6.65×10^{2} 2.80×10^{3}
RANGE, 0.1-0.2 500 feet 170 feet 45 feet	1.44×10^{3} 1.95×10^{3} 1.70×10^{3}	1.34×10^{3} 1.28×10^{3} 3.05×10^{3}	1.72×10^{3} 4.36×10^{3} 2.20×10^{3}	2.93×10^{3} 4.81×10^{3} 4.04×10^{3}	3.20×10^{3} 4.77×10^{3} 2.98×10^{3}	1.96×10^{3} 2.91×10^{3} 3.58×10^{3}	3.13×10^{3} 5.70×10^{2} 2.67×10^{3}
RANGE, 0.2-0.3 500 feet 170 feet 45 feet	1.16×10^{2} 1.83×10^{2} 7.3×10^{1}	1.45×10^{2} 3.28×10^{2} 2.61×10^{2}	1.45×10^{2} 3.57×10^{2} 2.41×10^{2}	1.23×10^{2} 5.44×10^{2} 2.30×10^{2}	1.97×10^{2} 2.22×10^{2} 1.87×10^{2}	1.56×10^{2} 1.80×10^{2} 2.74×10^{2}	2.10×10^{2} 2.7×10^{1} 2.03×10^{2}
RANGE, 0.3-0.5 500 feet 170 feet 45 feet	6.0×10^{1} 9.6×10^{1} 1.59×10^{2}	5.4×10^{1} 9.0×10^{1} 1.38×10^{2}	8.4×10^{1} 1.44×10^{2} 1.20×10^{2}	5.27×10^{1} 2.01×10^{2} 9.46×10^{1}	8.75×10^{1} 9.46×10^{1} 9.52×10^{1}	5.27×10^{1} 6.83×10^{1} 1.09×10^{2}	7.91×10^{1} 9.50 7.19×10^{1}
RANGE, 0.5-1.0 500 feet 170 feet 45 feet	2.82 3.06 3.27	3. 3.27 3.73	3.03 3.76 3.64	4.15 4.81 6.96	4.4 4.47 4.80	3.52 4.48 5.5	3.75 4.58 4.36
RANGE, 1.0-2.0 500 feet 170 feet 45 feet	0.44 0.68 1.06	0.55 0.72 0.97	0.54 1.00 0.93	0.94 1.46 2.76	1.04 1.23 1.34	0.66 1.20 1.77	0.84 0.91 1.28
RANGE, 2.0-8.0 500 feet 170 feet 45 feet	0.19 0.35 0.34	0.21 0.30 0.35	0.21 0.41 0.36	0.26 0.43 0.48	0.23 0.38 0.35	0.18 0.37 0.43	0.21 0.15 0.36

Table A-XII Particle number data for the period 1815-2135, 19 July 1967.

TIME (mid sample)	2145	2155	2205	2215	2225	2235	2245	2255	2305	2315	2325	2335	2345	2355	0005	0015	0025	0035	0045	0055	0105
PARTICLES /CM^3 (diameter-micron)																					
TOTAL, 0.002-8.0																					
500 feet	2.13×10^{4}			1.43×10^{4}			1.24×10^{4}			1.49×10^{4}			1.36×10^{4}			1.22×10^{4}			9.81×10^{3}		
170 feet		3.73×10^{4}			3.88×10^{4}			4.01×10^{4}			3.32×10^{4}			3.73×10^{4}			2.60×10^{4}			2.87×10^{4}	
45 feet			6.15×10^{4}			7.84×10^{4}			1.00×10^{5}			9.51×10^{4}			7.40×10^{4}			7.53×10^{4}			5.61×10^{4}
RANGE, 0.002-0.02																					
500 feet	4.64×10^{3}			2.97×10^{3}			3.46×10^{3}			1.24×10^{3}			1.98×10^{3}			2.23×10^{3}			1.24×10^{3}		
170 feet		3.34×10^{4}			1.73×10^{4}			1.60×10^{4}			1.35×10^{4}			1.21×10^{4}			8.53×10^{3}			1.07×10^{4}	
45 feet			4.03×10^{4}			5.32×10^{4}			6.83×10^{4}			7.03×10^{4}			5.11×10^{4}			4.95×10^{4}			3.82×10^{4}
RANGE, 0.02-0.03																					
500 feet	3.69×10^{3}			2.89×10^{3}			1.76×10^{3}			2.73×10^{3}			2.89×10^{3}			2.41×10^{3}			1.28×10^{3}		
170 feet		8.95×10^{2}			4.87×10^{3}			6.87×10^{3}			4.79×10^{3}			4.79×10^{3}			4.47×10^{3}			5.27×10^{3}	
45 feet			2.55×10^{3}			6.69×10^{3}			1.96×10^{4}			5.89×10^{3}			4.94×10^{3}			4.62×10^{3}			3.66×10^{3}
RANGE, 0.03-0.04																					
500 feet	3.43×10^{3}			1.66×10^{3}			1.66×10^{3}			2.98×10^{3}			2.54×10^{3}			1.99×10^{3}			1.77×10^{3}		
170 feet		7.49×10^{2}			4.35×10^{3}			5.18×10^{3}			4.41×10^{3}			3.75×10^{3}			3.25×10^{3}			3.42×10^{3}	
45 feet			4.73×10^{3}			5.94×10^{3}			6.49×10^{3}			5.50×10^{3}			4.40×10^{3}			6.38×10^{3}			3.52×10^{3}
RANGE, 0.04-0.06																					
500 feet	3.59×10^{3}			2.11×10^{3}			1.64×10^{3}			3.08×10^{3}			2.28×10^{3}			1.64×10^{3}			1.72×10^{3}		
170 feet		8.73×10^{2}			4.29×10^{3}			4.83×10^{3}			3.98×10^{3}			4.21×10^{3}			3.55×10^{3}			2.96×10^{3}	
45 feet			5.61×10^{3}			4.20×10^{3}			7.24×10^{3}			5.29×10^{3}			6.07×10^{3}			5.84×10^{3}			3.50×10^{3}
RANGE, 0.06-0.08																					
500 feet	1.85×10^{3}			1.46×10^{3}			1.19×10^{3}			1.88×10^{3}			1.35×10^{3}			1.37×10^{3}			1.21×10^{3}		
170 feet		4.84×10^{2}			3.38×10^{3}			2.74×10^{3}			2.55×10^{3}			2.04×10^{3}			2.36×10^{3}			2.42×10^{3}	
45 feet			3.51×10^{2}			3.25×10^{3}			5.48×10^{3}			3.57×10^{3}			3.19×10^{3}			4.53×10^{3}			2.04×10^{3}
RANGE, 0.08-0.1																					
500 feet	1.60×10^{3}			1.55×10^{3}			1.07×10^{3}			1.70×10^{3}			1.16×10^{3}			1.03×10^{3}			1.05×10^{3}		
170 feet		4.40×10^{2}			2.30×10^{3}			2.26×10^{3}			2.18×10^{3}			1.89×10^{3}			1.75×10^{3}			1.89×10^{3}	
45 feet			2.60×10^{3}			2.43×10^{3}			2.80×10^{3}			2.63×10^{3}			1.96×10^{3}			2.26×10^{3}			2.78×10^{3}
RANGE, 0.1-0.2																					
500 feet	2.19×10^{3}			1.52×10^{3}			1.45×10^{3}			1.18×10^{3}			1.27×10^{3}			1.35×10^{3}			1.39×10^{3}		
170 feet		4.42×10^{2}			2.04×10^{3}			2.06×10^{3}			1.58×10^{3}			2.09×10^{3}			1.87×10^{3}			1.92×10^{3}	
45 feet			1.86×10^{3}			2.42×10^{3}			2.52×10^{3}			1.69×10^{3}			2.10×10^{3}			1.88×10^{3}			2.21×10^{3}
RANGE, 0.2-0.3																					
500 feet	2.30×10^{2}			8.69×10^{1}			1.02×10^{2}			8.88×10^{1}			9.46×10^{1}			1.57×10^{2}			1.14×10^{2}		
170 feet		1.54×10^{1}			1.64×10^{2}			1.10×10^{2}			1.35×10^{2}			1.97×10^{2}			1.66×10^{2}			5.01×10^{1}	
45 feet			2.16×10^{2}			1.91×10^{2}			1.72×10^{2}			1.35×10^{2}			1.72×10^{2}			2.51×10^{2}			1.87×10^{2}
RANGE, 0.3-0.5																					
500 feet	6.65×10^{1}			3.95×10^{1}			3.36×10^{1}			4.2×10^{1}			3.71×10^{1}			7.61×10^{1}			4.55×10^{1}		
170 feet		7.79			5.39×10^{3}			5.15×10^{1}			5.99×10^{1}			4.07×10^{1}			4.91×10^{1}			5.75×10^{1}	
45 feet			6.35×10^{1}			5.99×10^{1}			6.83×10^{1}			5.87×10^{1}			6.71×10^{1}			7.07×10^{1}			6.95×10^{1}
RANGE, 0.5-1.0																					
500 feet	3.04			2.63			2.69			2.71			2.72			2.84			2.07		
170 feet		3.92			3.61			3.42			2.72			3.13			3.20			3.34	
45 feet			4.03			4.10			4.29			3.68			3.58			3.76			3.78
RANGE, 1.0-2.0																					
500 feet	0.52			0.44			0.49			0.54			0.56			0.5			0.43		
170 feet		0.76			1.06			0.97			0.81			0.97			0.89			1.07	
45 feet			1.21			1.17			1.50			1.10			1.03			1.09			1.16
RANGE, 2.0-8.0																					
500 feet	0.17			0.22			0.25			0.28			0.03			0.22			0.19		
170 feet		0.18			0.43			0.40			0.38			0.45			0.43			0.44	
45 feet			0.44			0.40			0.48			0.40			0.40			0.42			0.40

Table A-XIII Particle number data for the periods 2145-2355, 19 July 1967 and 0005-0105, 20 July 1967.

TIME (mid sample)	0115 0125 0135	0145 0155 0205	0215 0225 0235	0245 0255 0305	0315 0325 0335	0345 0355 0405	0415 0425 0435
PARTICLES / CM^3 (diameter-micron)							
TOTAL, 0.002-8.0							
500 feet	2.40×10^{4}	1.14×10^{4}	8.51×10^{3}	1.08×10^{4}	5.54×10^{3}	1.37×10^{4}	8.36×10^{3}
170 feet	4.14×10^{4}	3.09×10^{4}	2.33×10^{4}	1.55×10^{4}	2.09×10^{4}	1.68×10^{4}	1.39×10^{4}
45 feet	8.04×10^{4}	4.81×10^{4}	5.89×10^{4}	8.18×10^{4}	5.97×10^{4}	9.48×10^{4}	3.73×10^{4}
RANGE, 0.002-0.02							
500 feet	9.89×10^{2}	2.72×10^{3}	1.36×10^{3}	1.21×10^{3}	1.73×10^{2}	3.59×10^{3}	1.98×10^{3}
170 feet	2.01×10^{4}	1.40×10^{4}	1.06×10^{4}	1.50×10^{3}	9.56×10^{3}	7.18×10^{3}	3.99×10^{3}
45 feet	5.04×10^{4}	3.32×10^{4}	4.20×10^{4}	5.87×10^{4}	3.66×10^{4}	7.25×10^{4}	5.62×10^{3}
RANGE, 0.02-0.03							
500 feet	1.72×10^{4}	1.44×10^{3}	1.36×10^{3}	2.65×10^{3}	4.81×10^{2}	2.81×10^{3}	1.12×10^{3}
170 feet	6.63×10^{3}	1.92×10^{3}	2.07×10^{3}	3.35×10^{3}	2.88×10^{3}	8.0×10^{1}	1.36×10^{3}
45 feet	1.15×10^{4}	2.39×10^{3}	3.98×10^{3}	2.23×10^{3}	5.89×10^{3}	6.21×10^{3}	3.31×10^{3}
RANGE, 0.03-0.04							
500 feet	1.10×10^{3}	1.44×10^{3}	1.16×10^{3}	1.38×10^{3}	1.02×10^{3}	1.28×10^{3}	6.07×10^{2}
170 feet	4.24×10^{3}	3.75×10^{3}	2.65×10^{3}	2.20×10^{3}	1.65×10^{3}	1.71×10^{3}	1.05×10^{3}
45 feet	5.12×10^{3}	2.53×10^{3}	1.76×10^{3}	3.19×10^{3}	3.74×10^{3}	3.91×10^{3}	2.23×10^{3}
RANGE, 0.04-0.06							
500 feet	1.42×10^{3}	1.83×10^{3}	1.29×10^{3}	1.48×10^{3}	5.38×10^{2}	1.79×10^{3}	9.36×10^{2}
170 feet	3.90×10^{3}	4.29×10^{3}	2.03×10^{3}	2.26×10^{3}	1.48×10^{3}	2.73×10^{3}	1.95×10^{3}
45 feet	2.18×10^{3}	3.39×10^{3}	4.83×10^{3}	6.85×10^{3}	2.49×10^{3}	3.78×10^{3}	2.41×10^{3}
RANGE, 0.06-0.08							
500 feet	9.18×10^{2}	1.17×10^{3}	9.88×10^{2}	1.06×10^{3}	8.73×10^{2}	1.63×10^{3}	1.09×10^{3}
170 feet	2.17×10^{3}	2.74×10^{3}	2.07×10^{3}	2.14×10^{3}	1.63×10^{3}	2.29×10^{3}	1.69×10^{3}
45 feet	5.55×10^{3}	2.39×10^{3}	2.17×10^{3}	6.25×10^{3}	2.23×10^{3}	2.68×10^{3}	2.11×10^{3}
RANGE, 0.08-0.1							
500 feet	1.03×10^{3}	1.46×10^{3}	9.79×10^{2}	1.46×10^{3}	1.05×10^{3}	1.21×10^{3}	1.04×10^{3}
170 feet	1.94×10^{3}	2.36×10^{3}	1.82×10^{3}	1.99×10^{3}	1.68×10^{3}	2.49×10^{3}	1.80×10^{3}
45 feet	2.67×10^{3}	2.28×10^{3}	2.96×10^{3}	2.25×10^{3}	4.43×10^{3}	2.75×10^{3}	1.88×10^{3}
RANGE, 0.1-0.2							
500 feet	1.18×10^{3}	1.21×10^{3}	1.21×10^{3}	1.43×10^{3}	1.26×10^{3}	1.26×10^{3}	1.39×10^{3}
170 feet	2.13×10^{3}	1.65×10^{3}	1.90×10^{3}	1.80×10^{3}	1.78×10^{3}	1.86×10^{3}	1.84×10^{3}
45 feet	2.67×10^{3}	1.66×10^{3}	1.01×10^{3}	2.11×10^{3}	3.89×10^{3}	2.70×10^{3}	1.70×10^{3}
RANGE, 0.2-0.3							
500 feet	1.06×10^{2}	1.03×10^{2}	1.06×10^{2}	1.34×10^{2}	1.06×10^{2}	1.24×10^{2}	1.51×10^{2}
170 feet	2.08×10^{2}	1.49×10^{2}	1.58×10^{2}	2.18×10^{2}	2.03×10^{2}	1.32×10^{2}	1.68×10^{2}
45 feet	1.85×10^{2}	1.74×10^{2}	1.29×10^{2}	2.08×10^{2}	2.94×10^{2}	1.97×10^{2}	1.60×10^{2}
RANGE, 0.3-0.5							
500 feet	4.55×10^{1}	4.73×10^{1}	4.91×10^{1}	4.49×10^{1}	3.71×10^{1}	4.43×10^{1}	4.31×10^{1}
170 feet	7.07×10^{1}	7.31×10^{1}	6.59×10^{1}	5.93×10^{1}	5.21×10^{1}	5.69×10^{1}	5.09×10^{1}
45 feet	6.83×10^{1}	7.31×10^{1}	5.75×10^{1}	7.19×10^{1}	6.00×10^{1}	6.59×10^{1}	4.43×10^{1}
RANGE, 0.5-1.0							
500 feet	2.76	2.77	2.83	2.83	2.65	2.96	2.95
170 feet	3.87	3.42	3.21	3.00	3.34	3.64	3.17
45 feet	4.24	3.79	3.39	3.53	3.86	3.84	3.60
RANGE, 1.0-2.0							
500 feet	0.38	0.35	0.43	0.35	0.29	0.46	0.43
170 feet	1.46	1.10	1.03	0.91	1.18	1.2	1.39
45 feet	1.39	1.19	0.98	1.10	1.09	1.09	1.02
RANGE, 2.0-8.0							
500 feet	0.15	0.13	0.18	0.12	0.11	0.21	0.17
170 feet	0.50	0.51	0.48	0.45	0.47	0.43	0.33
45 feet	0.41	0.42	0.42	0.41	0.40	0.41	0.43

Table A-XIV Particle number data for the period 0115-0435, 20 July 1967.

TIME (mid sample)	0445 0455 0505	0515 0525 0535	0545 0555 0605	0615 0625 0635	0645 0655 0705	0715 0725 0735	0745 0755 0805
PARTICLES / CM^3 (diameter-micron)							
TOTAL, 0.002-8.0 500 feet 170 feet 45 feet	8.55×10^3 1.34×10^4 9.30×10^4	9.09×10^3 2.37×10^4 1.70×10^5	1.86×10^4 2.68×10^4 1.65×10^5	2.29×10^4 4.61×10^4 1.86×10^5	2.09×10^4 6.33×10^4 2.26×10^5	2.41×10^4 8.29×10^4 2.03×10^5	4.79×10^4 9.22×10^4 1.45×10^5
RANGE, 0.002-0.02 500 feet 170 feet 45 feet	1.11×10^3 2.40×10^3 7.31×10^4	7.41×10^2 9.58×10^3 9.92×10^4	1.85×10^3 4.96×10^3 1.24×10^5	5.44×10^3 1.96×10^4 1.44×10^5	6.18×10^3 3.57×10^4 1.75×10^5	5.19×10^3 4.29×10^4 1.26×10^5	1.36×10^4 5.20×10^4 8.81×10^4
RANGE, 0.02-0.03 500 feet 170 feet 45 feet	1.20×10^3 1.04×10^3 2.07×10^3	9.62×10^2 3.51×10^2 3.30×10^4	5.05×10^3 4.15×10^3 7.64×10^3	6.89×10^3 4.95×10^3 8.12×10^3	4.65×10^3 6.79×10^3 1.50×10^4	6.57×10^3 1.13×10^4 3.23×10^4	1.25×10^4 3.83×10^3 2.09×10^4
RANGE, 0.03-0.04 500 feet 170 feet 45 feet	9.39×10^2 2.15×10^3 3.41×10^3	1.77×10^3 1.58×10^3 2.56×10^4	3.31×10^3 5.46×10^3 1.01×10^4	3.09×10^3 6.95×10^3 1.28×10^4	2.54×10^3 6.56×10^3 5.83×10^3	3.65×10^3 9.26×10^3 1.73×10^4	7.84×10^3 9.59×10^3 1.18×10^4
RANGE, 0.04-0.06 500 feet 170 feet 45 feet	1.09×10^3 2.30×10^3 6.03×10^3	1.17×10^3 2.69×10^3 5.53×10^3	3.20×10^3 4.87×10^3 1.05×10^4	2.42×10^3 6.31×10^3 9.66×10^3	2.42×10^3 6.08×10^3 1.25×10^4	2.85×10^3 6.74×10^3 1.39×10^4	6.01×10^3 1.08×10^4 1.13×10^4
RANGE, 0.06-0.08 500 feet 170 feet 45 feet	1.40×10^3 1.63×10^3 4.49×10^3	1.64×10^3 5.67×10^3 2.57×10^3	1.85×10^3 2.71×10^3 5.51×10^3	1.53×10^3 4.53×10^3 3.89×10^3	1.66×10^3 3.31×10^3 1.08×10^4	2.49×10^3 5.39×10^3 6.05×10^3	4.02×10^3 7.01×10^3 5.67×10^3
RANGE, 0.08-0.1 500 feet 170 feet 45 feet	1.27×10^3 1.75×10^3 1.83×10^3	1.33×10^3 2.02×10^3 1.99×10^3	1.26×10^3 1.91×10^3 3.67×10^3	1.49×10^3 3.27×10^3 3.30×10^3	1.44×10^3 2.26×10^3 3.56×10^3	1.59×10^3 3.69×10^3 4.03×10^3	1.90×10^3 4.61×10^3 3.72×10^3
RANGE, 0.1-0.2 500 feet 170 feet 45 feet	1.37×10^3 1.89×10^3 1.84×10^3	1.30×10^3 1.59×10^3 2.22×10^3	1.92×10^3 2.49×10^3 3.33×10^3	1.84×10^3 2.20×10^2 3.26×10^3	1.81×10^3 2.38×10^3 3.05×10^3	1.64×10^3 3.20×10^3 3.27×10^3	1.84×10^3 4.02×10^3 3.17×10^3
RANGE, 0.2-0.3 500 feet 170 feet 45 feet	1.16×10^2 1.91×10^2 1.64×10^2	1.48×10^2 1.92×10^2 2.17×10^2	1.30×10^2 1.47×10^2 1.94×10^2	9.26×10^1 1.78×10^2 2.39×10^2	1.14×10^2 2.14×10^2 2.16×10^2	1.14×10^2 2.49×10^2 2.22×10^2	1.31×10^2 2.12×10^2 2.12×10^2
RANGE, 0.3-0.5 500 feet 170 feet 45 feet	4.67×10^1 5.87×10^1 6.11×10^1	4.43×10^1 5.45×10^1 5.21×10^1	5.21×10^1 5.73×10^1 4.49×10^1	5.51×10^1 6.83×10^1 8.99×10^1	6.71×10^1 5.15×10^1 5.33×10^1	4.61×10^1 6.47×10^1 8.27×10^1	4.91×10^1 7.79×10^1 7.79×10^1
RANGE, 0.5-1.0 500 feet 170 feet 45 feet	2.90 3.23 3.69	3.04 3.4 4.12	3.03 3.5 4.27	3.09 3.84 4.40	3.04 3.9 4.51	3.07 4.34 5.15	3.39 4.45 5.19
RANGE, 1.0-2.0 500 feet 170 feet 45 feet	0.35 0.83 0.95	0.49 0.87 1.20	0.53 0.85 1.20	0.50 0.93 1.19	0.52 0.96 1.17	0.50 1.05 1.31	0.70 1.11 1.20
RANGE, 2.0-8.0 500 feet 170 feet 45 feet	0.13 0.34 0.29	0.20 0.35 0.40	0.22 0.33 0.50	0.22 0.37 0.48	0.20 0.40 0.42	0.22 0.39 0.42	0.26 0.41 0.39

Table A-XV   Particle number data for the period 0445-0805, 20 July 1967.

TIME (mid sample)	0815	0825	0835	0845	0855	0905	0915	0925	1755	1805	1815	1825	1835	1845	1855	1905	1915	1925	1935	1945
PARTICLES / CM^3 (diameter-micron)																				
TOTAL, 0.002-8.0																				
500 feet	7.31×10^{4}			2.78×10^{5}			2.75×10^{5}		2.95×10^{4}			7.41×10^{4}			4.45×10^{4}			9.24×10^{4}		
170 feet		1.64×10^{5}			1.54×10^{5}			1.15×10^{5}		9.92×10^{4}			8.50×10^{4}			6.60×10^{4}			4.56×10^{4}	
45 feet			2.02×10^{5}			2.19×10^{5}					2.02×10^{5}			7.42×10^{4}			1.19×10^{5}			1.10×10^{5}
RANGE, 0.002-0.02																				
500 feet	2.96×10^{4}			1.29×10^{5}			6.55×10^{4}		4.94×10^{2}			4.50×10^{4}			2.20×10^{4}			4.38×10^{4}		
170 feet		8.64×10^{4}			7.38×10^{3}			3.54×10^{4}		4.86×10^{4}			3.23×10^{4}			2.30×10^{4}			1.71×10^{4}	
45 feet			1.21×10^{5}			3.50×10^{4}					8.04×10^{4}			4.29×10^{4}			5.93×10^{4}			4.87×10^{4}
RANGE, 0.02-0.03																				
500 feet	1.27×10^{4}			6.85×10^{4}			8.18×10^{4}		1.60×10^{2}			5.77×10^{3}			4.97×10^{3}			8.50×10^{3}		
170 feet		4.14×10^{4}			1.60×10^{3}			4.79×10^{2}		9.58×10^{2}			9.90×10^{3}			3.19×10^{3}			6.39×10^{2}	
45 feet			4.14×10^{4}			2.38×10^{2}					2.90×10^{4}			5.73×10^{3}			2.09×10^{4}			1.37×10^{4}
RANGE, 0.03-0.04																				
500 feet	1.02×10^{4}			5.36×10^{4}			4.23×10^{4}		2.21×10^{2}			7.62×10^{3}			5.41×10^{3}			1.01×10^{4}		
170 feet		1.20×10^{4}			1.10×10^{4}			8.82×10^{2}		2.87×10^{3}			1.27×10^{4}			1.37×10^{4}			7.06×10^{3}	
45 feet			1.32×10^{4}			2.46×10^{4}					4.05×10^{4}			7.59×10^{3}			1.36×10^{4}			1.20×10^{4}
RANGE, 0.04-0.06																				
500 feet	8.50×10^{3}			1.54×10^{4}			1.97×10^{4}		3.90×10^{2}			6.75×10^{3}			5.31×10^{3}			1.47×10^{4}		
170 feet		1.13×10^{4}			3.27×10^{4}			3.89×10^{2}		1.71×10^{4}			1.72×10^{4}			1.52×10^{4}			1.25×10^{4}	
45 feet			1.08×10^{4}			4.40×10^{4}					3.00×10^{4}			8.16×10^{8}			1.20×10^{4}			1.25×10^{4}
RANGE, 0.06-0.08																				
500 feet	5.86×10^{3}			4.08×10^{3}			1.47×10^{4}		5.86×10^{3}			4.24×10^{3}			2.87×10^{3}			1.00×10^{4}		
170 feet		6.18×10^{3}			3.99×10^{4}			1.30×10^{4}		1.94×10^{4}			7.64×10^{3}			6.05×10^{3}			2.61×10^{3}	
45 feet			7.90×10^{3}			3.35×10^{4}					1.12×10^{4}			4.14×10^{3}			5.86×10^{3}			1.10×10^{4}
RANGE, 0.08-0.1																				
500 feet	3.30×10^{3}			3.48×10^{3}			2.31×10^{4}		1.22×10^{4}			2.30×10^{3}			2.04×10^{3}			3.31×10^{3}		
170 feet		2.04×10^{3}			3.36×10^{4}			3.03×10^{4}		5.81×10^{3}			2.91×10^{3}			2.57×10^{3}			2.83×10^{3}	
45 feet			3.93×10^{3}			3.88×10^{4}					5.55×10^{3}			2.91×10^{3}			3.43×10^{3}			7.28×10^{3}
RANGE, 0.1-0.2																				
500 feet	2.80×10^{3}			2.90×10^{3}			2.52×10^{4}		9.01×10^{3}			2.20×10^{3}			1.73×10^{3}			1.88×10^{3}		
170 feet		4.11×10^{3}			2.63×10^{4}			3.20×10^{4}		4.10×10^{3}			2.28×10^{3}			2.02×10^{3}			2.55×10^{3}	
45 feet			3.44×10^{3}			4.09×10^{4}					4.51×10^{3}			2.60×10^{3}			3.17×10^{3}			4.47×10^{3}
RANGE, 0.2-0.3																				
500 feet	1.58×10^{2}			2.34×10^{2}			2.42×10^{3}		8.49×10^{2}			1.62×10^{2}			1.53×10^{2}			1.06×10^{2}		
170 feet		2.84×10^{2}			1.48×10^{3}			1.95×10^{3}		2.72×10^{2}			9.65×10^{1}			1.81×10^{2}			1.60×10^{2}	
45 feet			2.43×10^{2}			1.47×10^{3}					3.42×10^{2}			1.54×10^{2}			3.01×10^{2}			3.71×10^{2}
RANGE, 0.3-0.5																				
500 feet	6.23×10^{1}			8.89×10^{1}			1.65×10^{2}		2.94×10^{2}			7.07×10^{1}			7.31×10^{1}			4.67×10^{1}		
170 feet		7.19×10^{1}			2.67×10^{2}			4.73×10^{2}		9.11×10^{1}			5.99×10^{1}			5.51×10^{1}			7.61×10^{1}	
45 feet			7.55×10^{1}			4.07×10^{2}					1.44×10^{2}			7.19×10^{1}			6.59×10^{1}			9.64×10^{1}
RANGE, 0.5-1.0																				
500 feet	4.8			4.08			4.36		3.15			3.11			3.5			5.08		
170 feet		4.47			4.91			4.52		1.28×10^{1}			5.15			4.53			4.12	
45 feet			5.21			7.04					1.54×10^{1}			3.90			5.25			6.95
RANGE, 1.0-2.0																				
500 feet	1.02			0.98			0.96		0.38			0.38			0.60			1.18		
170 feet		1.26			1.18			1.22		2.13			0.82			1.03			0.94	
45 feet			2.35			1.41					2.49			0.74			1.26			2.03
RANGE, 2.0-8.0																				
500 feet	0.34			0.33			0.35		0.14			0.13			0.23			0.21		
170 feet		0.48			0.49			0.48		0.34			0.26			0.28			0.35	
45 feet			0.40			0.52					0.33			0.30			0.27			0.41

Table A-XVI Particle number data for the periods 0815-0925 and 1755-1945, 20 July 1967.

TIME (mid sample)	1010	1020	1030	1040	1050	1100	1110	1120	1130	1140	1150	1200	1210	1220	1230	1240	1250	1300	1310
PARTICLES /CM^{3} (DIAMETER-MICRON)																			
TOTAL, 0.002-8.0																			
500 feet		2.81x10^{4}			4.41x10^{4}			4.45x10^{4}			2.91x10^{4}			3.77x10^{4}			3.05x10^{4}		
170 feet			6.08x10^{4}			7.88x10^{4}						5.23x10^{4}			3.03x10^{4}			6.61x10^{4}	
45 feet	1.13x10^{5}			1.25x10^{5}			1.16x10^{5}			8.96x10^{4}			1.09x10^{5}			7.54x10^{4}			7.86x10^{4}
RANGE, 0.002-0.02																			
500 feet		1.11x10^{4}			3.04x10^{4}			3.04x10^{4}			1.67x10^{4}			1.70x10^{4}			1.27x10^{4}		
170 feet			3.48x10^{4}			5.74x10^{4}						3.78x10^{4}			2.70x10^{4}			4.77x10^{4}	
45 feet	5.80x10^{4}			8.46x10^{4}			8.98x10^{4}			6.69x10^{4}			8.92x10^{4}			4.75x10^{4}			4.77x10^{4}
RANGE, 0.02-0.03																			
500 feet		1.62x10^{2}			4.17x10^{3}			3.75x10^{3}			5.93x10^{3}			7.34x10^{3}			9.06x10^{3}		
170 feet			9.26x10^{3}			8.69x10^{3}						6.87x10^{3}			5.75x10^{2}			7.35x10^{3}	
45 feet	2.07x10^{3}			1.75x10^{4}			1.75x10^{3}			8.76x10^{3}			3.98x10^{3}			1.23x10^{4}			6.85x10^{3}
RANGE, 0.03-0.04																			
500 feet		6.07x10^{2}			2.82x10^{3}			3.65x10^{3}			2.96x10^{3}			4.05x10^{3}			4.00x10^{3}		
170 feet			4.74x10^{3}			3.75x10^{3}						3.31x10^{3}			1.22x10^{3}			5.29x10^{3}	
45 feet	2.75x10^{3}			6.38x10^{3}			1.03x10^{4}			4.13x10^{3}			6.61x10^{3}			6.05x10^{3}			1.11x10^{4}
RANGE, 0.04-0.06																			
500 feet		1.68x10^{3}			2.92x10^{3}			3.04x10^{3}			1.60x10^{3}			2.24x10^{3}			2.44x10^{3}		
170 feet			5.14x10^{3}			6.20x10^{3}						1.93x10^{3}			8.57x10^{2}			2.49x10^{3}	
45 feet	1.95x10^{3}			1.03x10^{4}			9.38x10^{3}			4.88x10^{3}			4.51x10^{3}			5.08x10^{3}			8.18x10^{3}
RANGE. 0.06-0.08																			
500 feet		3.19x10^{3}			2.40x10^{3}			2.03x10^{3}			1.03x10^{3}			1.17x10^{3}			1.05x10^{3}		
170 feet			2.74x10^{3}			8.60x10^{2}						1.15x10^{3}			1.98x10^{2}			2.14x10^{3}	
45 feet	1.12x10^{4}			1.78x10^{3}			2.01x10^{3}			3.57x10^{3}			2.14x10^{3}			2.10x10^{3}			1.40x10^{3}
RANGE, 0.08-0.1																			
500 feet		6.96x10^{3}			1.19x10^{3}			9.27x10^{2}			4.45x10^{2}			5.24x10^{3}			5.81x10^{2}		
170 feet			2.28x10^{3}			1.26x10^{3}						5.71x10^{2}			2.15x10^{2}			5.66x10^{2}	
45 feet	2.01x10^{4}			3.72x10^{3}			1.85x10^{3}			5.50x10^{2}			1.53x10^{3}			1.34x10^{3}			1.81x10^{3}
RANGE 0.1-0.2																			
500 feet		4.28x10^{3}			4.52x10^{2}			6.52x10^{2}			4.10x10^{2}			6.03x10^{2}			5.96x10^{2}		
170 feet			1.64x10^{3}			5.84x10^{2}						5.63x10^{2}			1.96x10^{2}			5.50x10^{2}	
45 feet	1.61x10^{4}			1.89x10^{3}			8.71x10^{2}			6.52x10^{2}			1.00x10^{3}			9.70x10^{2}			1.37x10^{3}
RANGE, 0.2-0.3																			
500 feet		1.08x10^{2}			2.97x10^{1}			4.52x10^{1}			4.25x10^{1}			4.05x10^{1}			4.25x10^{1}		
170 feet			1.35x10^{2}			1.97x10^{1}						4.05x10^{1}			3.92x10^{1}			3.47x10^{1}	
45 feet	1.06x10^{3}			5.96x10^{1}			2.9 x10^{1}			1.27x10^{2}			3.86x10^{1}			5.4 x10^{1}			7.14x10^{1}
RANGE, 0.3-0.5																			
500 feet		1.33x10^{1}			9.1			5.51			2.88x10^{1}			2.28x10^{1}			2.16x10^{1}		
170 feet			7.79x10^{1}			1.27x10^{1}						2.16x10^{1}			1.89x10^{1}			1.80x10^{1}	
45 feet	1.57x10^{2}			4.19			6.47			3.95x10^{1}			1.98x10^{1}			2.42x10^{1}			3.71x10^{1}
RANGE, 0.5-1.0																			
500 feet		2.50			2.57			2.58			2.27			2.24			2.25		
170 feet			2.46			2.53						2.29			2.34			2.35	
45 feet	2.58			3.34			2.57			2.6			2.39			2.39			2.44
RANGE, 1.0-2.0																			
500 feet		0.18			0.61			0.26			0.12			0.13			0.12		
170 feet			0.39			0.36						0.16			0.19			0.26	
45 feet	0.44			0.96			0.42			0.34			0.52			0.42			0.67
RANGE, 2.0-8.0																			
500 feet		0.12			0.44			0.14			0.06			0.08			0.07		
170 feet			0.42			0.25						0.10			0.05			0.16	
45 feet	0.31			0.65			0.26			0.11			0.44			0.30			0.40

Table A-XVII Particle number data for the period 1010-1310, 27 July 1967.

TIME (mid sample)	1320	1330	1340	1350	1400	1410	1420	1430	1440	1450	1500	1510	1520	1530	1540	1550	1600	1610
PARTICLES / CM^3 (diameter-micron)																		
TOTAL, 0.002-8.0																		
500 feet	2.40×10^{4}			2.45×10^{4}			2.73×10^{4}			1.43×10^{4}			1.96×10^{4}			4.35×10^{4}		
170 feet		4.65×10^{4}			6.78×10^{4}			3.40×10^{4}			3.21×10^{4}			4.60×10^{4}			7.56×10^{4}	
45 feet			1.09×10^{5}			7.56×10^{4}			9.01×10^{4}			1.05×10^{5}			6.25×10^{5}			9.39×10^{4}
RANGE, 0.002-0.02																		
500 feet	1.04×10^{4}			1.21×10^{4}			1.25×10^{4}			4.32×10^{3}			1.66×10^{3}			1.25×10^{4}		
170 feet		2.68×10^{4}			3.66×10^{4}			5.82×10^{4}			1.70×10^{4}			2.20×10^{4}			3.99×10^{4}	
45 feet			6.22×10^{4}			4.95×10^{4}			5.83×10^{4}			6.80×10^{4}			4.78×10^{4}			5.71×10^{4}
RANGE, 0.02-0.03																		
500 feet	4.17×10^{3}			2.81×10^{3}			4.32×10^{3}			2.97×10^{3}			7.02×10^{3}			1.52×10^{4}		
170 feet		2.95×10^{3}			1.52×10^{3}			3.80×10^{3}			1.17×10^{3}			9.74×10^{3}			1.28×10^{4}	
45 feet			2.40×10^{4}			5.57×10^{3}			1.77×10^{4}			2.44×10^{4}			3.02×10^{2}			1.27×10^{4}
RANGE, 0.03-0.04																		
500 feet	4.09×10^{3}			3.90×10^{3}			3.98×10^{3}			2.98×10^{3}			5.38×10^{3}			8.74×10^{3}		
170 feet		2.60×10^{3}			7.72×10^{2}			4.19×10^{3}			5.90×10^{3}			5.84×10^{3}			9.92×10^{3}	
45 feet			1.57×10^{4}			4.51×10^{3}			7.32×10^{3}			6.88×10^{3}			5.38×10^{3}			1.45×10^{4}
RANGE, 0.04-0.06																		
500 feet	2.65×10^{3}			2.93×10^{3}			3.53×10^{3}			2.06×10^{3}			2.90×10^{3}			4.38×10^{3}		
170 feet		7.55×10^{3}			5.34×10^{3}			3.90×10^{3}			5.56×10^{3}			5.22×10^{3}			7.95×10^{3}	
45 feet			4.77×10^{3}			1.06×10^{4}			3.44×10^{3}			3.36×10^{3}			3.00×10^{3}			4.98×10^{3}
RANGE, 0.06-0.08																		
500 feet	1.40×10^{3}			1.20×10^{3}			1.52×10^{3}			7.97×10^{2}			1.35×10^{3}			1.44×10^{3}		
170 feet		4.93×10^{3}			1.44×10^{4}			2.27×10^{3}			1.35×10^{3}			1.73×10^{3}			2.49×10^{3}	
45 feet			1.20×10^{3}			2.94×10^{3}			1.72×10^{3}			1.03×10^{3}			2.80×10^{3}			1.98×10^{3}
RANGE, 0.08-0.1																		
500 feet	6.81×10^{2}			9.09×10^{2}			9.64×10^{2}			6.98×10^{2}			7.96×10^{2}			7.33×10^{2}		
170 feet		8.17×10^{2}			6.54×10^{3}			1.05×10^{3}			6.44×10^{2}			8.30×10^{2}			1.57×10^{3}	
45 feet			6.70×10^{2}			1.63×10^{3}			1.03×10^{3}			8.33×10^{2}			1.95×10^{3}			2.62×10^{2}
RANGE, 0.1-0.2																		
500 feet	5.31×10^{2}			5.78×10^{2}			5.05×10^{2}			4.55×10^{2}			4.45×10^{2}			4.37×10^{2}		
170 feet		7.34×10^{2}			2.59×10^{3}			6.08×10^{2}			4.56×10^{2}			5.67×10^{2}			9.43×10^{2}	
45 feet			5.31×10^{2}			7.40×10^{2}			6.27×10^{2}			5.35×10^{2}			1.20×10^{3}			1.29×10^{3}
RANGE, 0.2-0.3																		
500 feet	3.28×10^{1}			1.99×10^{1}			1.22×10^{1}			2.66×10^{1}			2.18×10^{1}			3.09×10^{1}		
170 feet		3.57×10^{1}			4.09×10^{1}			2.22×10^{1}			2.66×10^{1}			5.54×10^{1}			9.84×10^{1}	
45 feet			5.21×10^{1}			7.89×10^{1}			3.22×10^{1}			2.66×10^{1}			6.31×10^{1}			1.04×10^{3}
RANGE, 0.3-0.5																		
500 feet	1.92×10^{1}			1.14×10^{1}			8.75			1.61×10^{1}			1.41×10^{1}			1.38×10^{1}		
170 feet		2.46×10^{1}			1.93×10^{1}			1.26×10^{1}			1.61×10^{1}			1.87×10^{1}			2.80×10^{1}	
45 feet			3.18×10^{1}			2.48×10^{1}			1.38×10^{1}			1.61×10^{1}			2.14×10^{1}			3.21×10^{1}
RANGE, 0.5-1.0																		
500 feet	2.31			2.31			2.34			2.31			2.44			2.30		
170 feet		2.37			2.52			2.32			2.32			2.43			2.65	
45 feet			2.35			2.36			2.35			2.40			2.44			2.5
RANGE, 1.0-2.0																		
500 feet	0.11			0.13			0.12			0.12			0.14			0.17		
170 feet		0.22			0.42			0.16			0.18			0.28			0.48	
45 feet			0.46			0.46			0.37			0.33			0.31			0.59
RANGE, 2.0-8.0																		
500 feet	0.06			0.08			0.06			0.05			0.06			0.08		
170 feet		0.10			0.30			0.11			0.10			0.14			0.30	
45 feet			0.27			0.26			0.14			0.17			0.17			0.32

Table A-XVIII Particle number data for the period 1320-1610, 27 July 1967.

TIME (mid sample)	1620	1630	1640	1650	1700	1710	1720
PARTICLES / CM^3 (DIAMETER-MICRON)							
TOTAL, 0.002-8.0							
500 feet	2.70×10^4			3.11×10^4			1.70×10^5
170 feet		9.61×10^4			5.06×10^4		
45 feet			8.78×10^4			7.90×10^4	
RANGE, 0.002-0.02							
500 feet	5.04×10^3			1.67×10^4			2.11×10^4
170 feet		1.48×10^4			3.28×10^4		
45 feet			7.14×10^4			6.06×10^4	
RANGE, 0.02-0.03							
500 feet	5.21×10^3			1.77×10^3			1.94×10^4
170 feet		2.89×10^4			4.95×10^3		
45 feet			3.34×10^2			4.24×10^3	
RANGE, 0.03-0.04							
500 feet	6.79×10^3			4.09×10^3			6.83×10^3
170 feet		2.99×10^4			2.24×10^3		
45 feet			1.54×10^2			4.84×10^3	
RANGE, 0.04-0.06							
500 feet	5.62×10^3			4.27×10^3			3.40×10^3
170 feet		1.84×10^4			6.02×10^3		
45 feet			7.65×10^3			5.29×10^3	
RANGE, 0.06-0.08							
500 feet	1.31×10^3			2.22×10^3			2.38×10^3
170 feet		2.07×10^3			2.19×10^3		
45 feet			4.64×10^3			2.08×10^3	
RANGE, 0.08-0.1							
500 feet	2.00×10^3			1.17×10^3			1.16×10^5
170 feet		1.11×10^3			1.24×10^3		
45 feet			2.51×10^3			1.26×10^3	
RANGE, 0.1-0.2							
500 feet	9.99×10^2			7.57×10^2			7.71×10^2
170 feet		9.11×10^2			9.43×10^2		
45 feet			1.09×10^3			6.70×10^2	
RANGE, 0.2-0.3							
500 feet	4.67×10^1			5.21×10^1			4.59×10^1
170 feet		6.37×10^1			1.57×10^2		
45 feet			2.22×10^1			4.54×10^1	
RANGE, 0.3-0.5							
500 feet	2.07×10^1			3.00×10^1			2.16×10^1
170 feet		2.52×10^1			4.89×10^1		
45 feet			1.86×10^1			2.28×10^1	
RANGE, 0.5-1.0							
500 feet	2.87			2.48			2.50
170 feet		2.76			2.47		
45 feet			2.81			2.36	
RANGE, 1.0-2.0							
500 feet	0.31			0.21			0.18
170 feet		0.24			0.22		
45 feet			0.38			0.24	
RANGE, 2.0-8.0							
500 feet	0.10			0.08			0.06
170 feet		0.15			0.10		
45 feet			0.17			0.12	

Table A-XIX Particle number data for the period 1620-1720, 27 July 1967.

APPENDIX B

Meteorological Data for Winter and Summer Sampling Periods

DATE	2-6-67															2-6-67		
TIME (mid sample)	0824	0840	0856	0912	0928	0944	1000	1016	1032	1048	1104	1120	1136	1152	1208	2205	2215	2225
TEMPERATURE (°F)																		
70 feet	-8.75	-7.25	-6.25	-4.75	-4.00	-2.25	-1.00	+0.75	+2.25	+4.00	+3.75	+4.00	+4.00	+4.50	+4.00	+3.75	+3.40	+2.60
170 feet	-8.85	-7.45	-6.93	-4.90	-4.23	-2.40	-1.18	+0.55	+1.85	+3.78	+3.23	+3.78	+3.80	+4.15	+3.83	+3.63	+3.29	+2.49
500 feet	-8.10	-6.60	-5.65	-4.35	-3.78	-2.17	-1.10	+0.45	+1.73	+3.65	+3.35	+3.65	+3.68	+4.15	+3.73	+3.63	+3.28	+2.48
RELATIVE HUMIDITY (%-ground level)	90	88	88.5	87	86.5	86	79	78	75	74	74	74	73	72	70	95	95.5	96
BAROMETRIC PRESSURE (mm.Hg-ground level)	750	750	749.8	749.7	749.7	749.7	749.7	749.7	749.7	749.7	749.6	749.6	749.6	749.6	749.5	744.6	744.6	744.7
WIND (direction-knots)																		
70 feet	ENE 3.0			ENE 4.0			ENE 2.5			ESE 7.0			ESE 8.0			ESE 2.5		
170 feet		ENE 6.0			E 3.0			E 3.0			ESE 8.0			ESE 8.0			SE 4.0	
500 feet			SE 9.0			SE 7.0			SE 3.0			ESE 8.0			SSE 7.0			SSE 7.0

DATE	2-6-67						2-7-67												
TIME (mid sample)	2235	2245	2255	2305	2315	2325	0825	0835	0845	0855	0905	0912	0917	0925	0935	0945	0955	1005	1015
TEMPERATURE (°F)																			
70 feet	+2.50	+2.25	+2.00	+2.15	+1.50	+1.15	+0.38	+0.50	+0.88	+1.50	+2.50	+3.20	+3.70	+4.25	+4.38	+4.43	+4.67	+4.78	+4.75
170 feet	+2.38	+2.18	+1.91	+2.09	+1.38	+1.05	+0.23	+0.38	+0.75	+1.33	+2.34	+3.06	+3.50	+4.06	+4.18	+4.25	+4.47	+4.63	+4.60
500 feet	+2.38	+2.18	+1.95	+2.14	+1.53	+1.24	+0.82	+0.93	+1.28	+1.77	+2.72	+3.34	+3.65	+4.10	+4.10	+4.11	+4.39	+4.51	+4.48
RELATIVE HUMIDITY (%-ground level)	96.5	97	97.5	98	98.5	98.5	100	100	100	100	100	100	100	100	100	100	100	99.5	99.5
BAROMETRIC PRESSURE (mm.Hg-ground level)	744.7	744.8	744.9	744.9	745	745	745.4	745.4	745.4	745.4	745.4	745.4	745.4	745.5	745.5	745.5	745.5	745.6	745.6
WIND (direction-knots)																			
70 feet	ESE 3.0			ESE 2.5			SSE 6.0			SSE 5.0				SE 7.5			SSE 7.0		
170 feet		SE 3.0			SE 3.0			SSE 9.0			SSE 8.0				SSE 7.0			SSE 8.0	
500 feet			SSE 11.0			S 11.0			SSE 16.5			S 13.0	S 13.0			S 13.0			SSW 12.0

Table B-I Micrometeorological data for the periods 0824-1208 and 2205-2325, 6 February 1967 and 0825-1015, 7 February 1967.

DATE	2-22-67																	
TIME (mid sample)	1055	1100	1105	1155	1200	1205	1255	1300	1305	1355	1400	1405	1455	1500	1505	1555	1600	1605
TEMPERATURE (^{o}F)																		
70 feet	+9.0			+10.5			+12.25			+13.5			+15.0			+14.75		
170 feet		+7.5			+9.0			+10.5			+12.0			+13.5			+13.5	
500 feet			+5.75			+7.5			+9.0			+10.5			+11.75			+11.75
RELATIVE HUMIDITY (%-ground level)	80			75			74			72			73			74.5		
BAROMETRIC PRESSURE (mm.Hg-ground level)	737.0			736.6			736.0			735.5			735.3			735.0		
WIND (direction-knots)																		
70 feet	NW 12			NW 13			WNW 12			WNW 11.5			WNW 10			WNW 10		
170 feet		NW 15			NW 14			NW 15			WNW 15			WNW 13			WNW 13	
500 feet			NW 15			NW 15			NW 15			WNW 15			WNW 15			WNW 15

Table B-II Micrometeorological data for the period 1055-1605, 22 February 1967.

TIME (mid sample)	1230	1240	1250	1300	1310	1320	1330	1340	1350	1400	1410	1420	1430	1440	1450	1500	1510	1520	1530	1540	1550
TEMPERATURE (°F)																					
500 feet	63	63	63.75	64	64.5	64	64.25	64.25	64.5	64.5	63.75	65	65	64.5	64.5	64.25	63	64	64.25	64.5	64.5
170 feet	65	65	65.5	66	66.75	66.25	66	66	66.5	66.5	65.75	67	67	66.5	66.5	66.5	65.25	66.5	66.25	66.5	66
70 feet	66	66	66.5	67	67.5	67	67	67	67.5	67.5	66.75	68	68	67	67	67	66	67	67	67	67
RELATIVE HUMIDITY (%)																					
500 feet	55.7			57.7			54.3			50.6			49.7			50.2			51		
170 feet		55.6			54.3			48.8			49.1			47.8			49.9			47.2	
70 feet			52.9			52			47.6			45.6			47.2			45.7			47.2
BAROMETRIC PRESSURE																					
500 feet (mm. Hg)	731.35			731.24			731.24			731.14			731.14			731.14			731.14		
170 feet		740.35			740.24			740.24			740.14			740.14			740.16			740.16	
70 feet			743.76			743.65			743.65			743.55			743.55			743.55			743.55
WIND (direction-knots)																					
500 feet		NNW 17			NW 19			NW 19			NW 22			NW 21			NW 22			NW 25	
170 feet		NW 14			NW 16			NW 16			NW 19			NW 16			NW 20			NW 20	
70 feet		NW 15			NW 16			NW 16			NW 18			NW 11			NW 16			NW 17	
DIRECT RADIATION CAL / CM² - MIN.	.65	.62	.77	.70	.88	.37	.39	.73	.75	.98	.74	.42	.56	.36	.52	.23	.43	.46	.57	.52	.63
SMOKE SPOT, COH				.15												.2					
SO², PPHM																					

TIME (mid sample)	1600	1610	1620	1630	1640	1650	1700	1710	1720	1740	1750	1800	1810	1820	1830	1840	1850	1900	1910	1920	1930
TEMPERATURE (°F)																					
500 feet	64.5	63.75	63.5	63.5	63.5	63.5	63.5	63.5	63.5	64	62.5	62.5	62.5	61.5	62.75	62.25	61.75	61.75	61.75	61.75	60.75
170 feet	66.5	65.75	65.75	65.5	65.5	65.5	65.5	65.5	65.5	66	64.5	64.5	64.5	63.5	63.5	64	63.5	63.5	63.5	63.5	62.5
70 feet	67	66.25	66.25	66	66	66	66	66	66	66.5	65	65	65	64	65	64.5	64	64	64	64	63
RELATIVE HUMIDITY (%)																					
500 feet	49.8			51			54.1			51.7			53.6			54.3			53		
170 feet		46.8			47.2			52			51.7			52.2			51.9			50.5	
70 feet			45.7			47.2			54.2			51.4			49			50.7			50.8
BAROMETRIC PRESSURE																					
500 feet (mm. Hg)	731.19			731.19			731.24			731.24			731.24			731.24			731.24		
170 feet		740.19			740.19			740.24			740.24			740.24			740.24			740.24	
70 feet			743.60			743.60			743.66			743.66			743.66			743.66			743.66
WIND (direction-knots)																					
500 feet		NW 22			NNW 21			NNW 19		NNW 21			NNW 22			NNW 20			NNW 20		
170 feet		NW 18			NNW 18			NW 16		NNW 16			NW 18			NW 16			NW 17		
70 feet		NW 17			NW 15			NW 16		NW 16			NW 16			NW 15			NW 16		
DIRECT RADIATION CAL / CM² - MIN.	.46	.45	.36	.44	.69	.71	.34	.18	.15	.23	.25	.25	.09	.14	.17	.15	.12	.12	.12	.16	.12
SMOKE SPOT, COH							.2											.15			
SO², PPHM																					

Table B-III Micrometeorological data for the period 1230-1930, 12 July 1967.

TIME (mid sample)	1940	1950	2000	2010	2020	2030	2040	2050	2100	2110	2120	2130	2140	2150	2200	2210	2220	2230	2240	2250	2300
TEMPERATURE (°F)																					
500 feet	61	61	61	60.75	60.5	60.5	60.75	61	61	60.5	60	60	60	60	60	60	60	60	60.5	59	59
170 feet	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62	61.5	61.5	61.5	61.5	61.75	61.5	61.5	61.5	62.5	60.75	60.75
70 feet	63	63	63	63	63	63	63	63	63	62.5	62	62	62	62	62	62	62	62	62.5	61	61
RELATIVE HUMIDITY (%)																					
500 feet	54.9			55			55			55.8			57.8			58.6			56.2		
170 feet		53.6			53.2			53.6			55.9			56.1			55.2			57.1	
70 feet			52.5			52.1			52.4			55.1			56			52.9			55.3
BAROMETRIC PRESSURE																					
500 feet (mm. Hg)	731.24			731.24			731.24			731.24			731.24			731.34			731.34		
170 feet		740.24			740.24			740.24			740.24			740.24			740.34			740.34	
70 feet			743.66			743.66			743.66			743.66			743.76			743.76			743.76
WIND (direction-knots)																					
500 feet	NNW 20			NNW 20			NNW 18			NNW 17			NNW 15			NNW 19			NNW 20		
170 feet	NW 16			NNW 15			NNW 12			NNW 12			NW 12			NW 14			NW 12		
70 feet	NW 15			NW 14			NNW 13			NW 12			NW 12			NW 13			NW 16		
DIRECT RADIATION CAL / CM^2-MIN.	.08	.06	.01	.02	.002																
SMOKE SPOT,COH									.15												.35
SO^2, PPHM																					

TIME (mid samples)	2310	2320	2330	2340	2350	2400	0010	0020	0030	0040	0050	0100	0110	0120	0130	0140	0150	0200	0210	0220	0230
TEMPERATURE (°F)																					
500 feet	59	58	58	58	57.5	57	57.25	57.25	57.25	57.25	56.25	56	56	56	55	55	55	55.25	54.5	54.5	54.75
170 feet	60.75	59.5	59.75	59.75	59.25	58.75	58.75	58.75	58.75	58.75	57.5	57.75	57.5	57.5	56.5	56.5	56.75	56.5	55.5	55.5	55.5
70 feet	61	60	60	60	59.5	59	59	59	59	59	58	58	58	58	57	57	57	57	56	56	56
RELATIVE HUMIDITY (%)																					
500 feet	58.7			59.8			60.8			61.3			63.9			64.1			66.2		
170 feet		59.4			59			58.3			61.5			61.8			64.1			66.8	
70 feet			57.4			59.6			57.5			61.7			63.8			63.1			64.8
BAROMETRIC PRESSURE																					
500 feet (mm. Hg)	731.34			731.34			731.48			731.48			731.48			731.48			731.50		
170 feet		740.34			740.34			740.45			740.45			740.45			740.45			740.50	
70 feet			743.76			743.86			743.86			743.86			743.86			743.91			743.91
WIND (direction-knots)																					
500 feet	NW 20			NW 20			NNW 21			NW 21			NNW 23			NNW 21			NNW 19		
170 feet	NW 14			NW 15			NW 15			NW 15			NW 16			NW 15			NW 11		
70 feet	NW 13			NW 14			NW 14			NW 14			NW 15			NW 14			NW 11		
DIRECT RADIATION CAL / CM^2-MIN.																					
SMOKE SPOT, COH												.2									
SO^2, PPHM																					

Table B-IV Micrometeorological data for the periods 1940-2400, 12 July 1967 and 0010-0230, 13 July 1967.

TIME (mid sample)	0240	0250	0300	0310	0320	0330	0340	0350	0400	0410	0420	0430	0440	0450	0500	0510	0520	0530	0540	0550
TEMPERATURE (°F)																				
500 feet	54.5	54.25	55	54.75	54.5	54.25	54	54	54	54	54	53.5	53	53.25	53	52.5	52.5	52.5	52.5	52.5
170 feet	55.5	55	55.5	55.75	55.5	55.75	55.5	55.5	55.5	55.5	55.5	55	54.5	54.5	54	53.5	53.5	53.5	53.5	53.5
70 feet	56	55.5	56	56	56	56	56	56	56	56	56	55.5	55	55	54.5	54	54	54	54	54
RELATIVE HUMIDITY (%)																				
500 feet	65.4			64.8			65.5			65.3			65.8			68.1				
170 feet		67.5			64.2			63.4			64.2			66.7			68			62.3
70 feet			63.9			63.7						63			67.7			64.6	63.5	
BAROMETRIC PRESSURE																				
500 feet (mm. Hg)	731.50			731.55			731.55			731.76			731.76			732.02				
170 feet		740.50			740.55			740.55			740.76			740.76			741.01			741.01
70 feet			743.96			743.96			744.17			744.17			744.43			744.43	744.43	
WIND (direction-knots)																				
500 feet	NNW 20			NNW 20			NNW 18			NNW 18			NNW 17			NNE 15			NNE 16	
170 feet	NNW 11			NNW 10			NNW 11			NNW 12			NNW 11			NNW 10			NNW 10	
70 feet	NW 10			NW 9			NW 10			NW 12			NNW 10			NNW 9			NNW 9	
DIRECT RADIATION CAL / CM^2-MIN.																				
SMOKE SPOT, COH			.2												.05					
SO^2, PPHM																				

TIME (mid sample)	0610	0620	0630----0700	0710	0720	0730----0740	0750	0810	0820----0840	0850	0900	0910	0920	0930	0940	0950	1000	1010
TEMPERATURE (°F)																		
500 feet	52.25	52.25		51.75	51.5		52.5	52.25		51.5	51.5	51.5	51.5	51.5	52	52	52	52.25
170 feet	53.5	53.5		53.5	53.5		54.5	55.4		53	53.5	53.5	53	53	53.5	54	54	54.25
70 feet	54	54		54	54		55	55		54	54	54	54	54	54.5	55	55	55
RELATIVE HUMIDITY (%)																		
500 feet					67.3		63.2			65.9			62.8			62.5		
170 feet		62.7									66.1			63.8			59.6	
70 feet	60.4			61.5				55.4				59.3			58.1			57.7
BAROMETRIC PRESSURE																		
500 feet (mm. Hg)					732.59		732.59			732.22			733.52			733.52		
170 feet		741.22									742.51			742.51			742.62	
70 feet	744.63			745				745.15				745.93			745.93			746.03
WIND (direction-knots)																		
500 feet	NNW 19			NNE 20				NNE 16		NNE 16		NNE 16			NNE 15			NNE 14
170 feet	NW 12			NNW 14				NNE 10		NNE 10		NNE 12			NNE 10			NNE 10
70 feet	NW 12			NNW 14				NNW 11		NNW 11		NNW 13			NNW 11			NNW 10
DIRECT RADIATION CAL / CM^2-MIN.	.028	.034		.293	.333		.44	.344		.073	.192	.158	.158	.569	.490	.321	.276	.395
SMOKE SPOT, COH											.25							
SO^2, PPHM																		

Table B-V Micrometeorological data for the period 0240-1010, 13 July 1967.

TIME (mid sample)	1020	1030	1040	1050	1100	1110	1120	1130	1140	1150	1200 —— 1450	1500	1510	1520	1530	1540	1550	1600	1610	1620
TEMPERATURE (^0F)																				
500 feet	52.5	52.5	52	52.25	52.25	52.5	52.75	53.75	54	54.25		63.25	63	63.75	63.5	63.5	64	64	64.5	64.5
170 feet	54.5	54	54	54	54	54.5	55	56	56.5	56.75		65	64.75	66	66	66	66	66.5	67	67
70 feet	55	55	55	55	55	55.5	56	57	57.5	58		66.5	66	67	67	67	67	67.5	68	68
RELATIVE HUMIDITY (%)																				
500 feet	60.2			62.6			63.1			60.3				45.3			44.1			45.8
170 feet		62.6			61.5			57.5				43.9			43			44.6		
70 feet			59.4			58.9			54				42.1			42.1			41.1	
BAROMETRIC PRESSURE																				
500 feet (mm. Hg)	733.62			733.72			733.72			733.72				732.64			732.64			732.22
170 feet		742.62			742.72			742.72				741.64			741.64			741.22		
70 feet			746.13			746.13			746.13				745.05			745.05			744.63	
WIND (direction-knots)																				
500 feet			NNE 16			NNE 14			NNE 14				NNW 15			NNW 18			NNW 16	
170 feet			NNW 12			NNE 9			NNE 8				NNW 12			NNW 14			NNW 12	
70 feet			NNW 13			NNW 10			NNW 9				NNW 12			NW 14			NW 12	
DIRECT RADIATION CAL / CM^2-MIN.	.304	.372	.496	.552	.834	.913	1.274	1.116	1.319	1.454		1.15	1.172	1.093	.936	1.127	1.125	1.026	1.015	.947
SMOKE SPOT, COH					.3							.15								
SO^2, PPHM																				

Table B-VI Micrometeorological data for the periods 1020-1150 and 1500-1620, 13 July 1967.

TIME(mid sample)	1455	1505	1515	1525	1535	1545	1555	1605	1615	1625	1635	1645	1655	1705	1715	1725	1735	1745	1755	1805
TEMPERATURE (°F)																				
500 feet	81	81	80.5	81.25	81	81.5	81.5	81.5	82	81.5	81.5	81	80.5	80.75	81	81.75	82	82	81.5	81.75
170 feet	83	83	82	83	83	83	83	83	83.5	83	83	83.5	82	82.5	82.5	83.5	83.5	83.5	83.5	83.5
70 feet	84	84	83	84	84	84	84	84	84.5	84	84	84	83	83	83	84	84	84	84	84
RELATIVE HUMIDITY (%)																				
500 feet			46.5			47.1			48.6			51.4			53			50.5		
170 feet	46.6			44.2			45.8			48.5			51.5			49.5			51.5	
70 feet		44.8			43.2			45.4			46.6			50.5			49.2			48
BAROMETRIC PRESSURE (mm. Hg)																				
500 feet			731.25			731.25			731.14			731.14			731.04			731.04		
170 feet	740.25			740.25			740.14			740.14			740.14			740.04			740.04	
70 feet		743.66			743.66			743.56			743.56			743.45			743.45			743.35
WIND (direction-knots)																				
500 feet	SSW 10	SSW 9			SSE 9			SSE 9			SSE 10			SSE 10			SSE 10			SSE 9
170 feet	SSE 7	SE 7			SE 7			SSE 8			SE 8			SEE 7			SE 7			SE 7
70 feet	SSE 8	SSE 6			SE 7			SE 7			SE 8			SE 9			SE 8			SE 7
DIRECT RADIATION (CAL/ CM²-MIN.)	1.24	1.18	1.17	1.15	1.15	1.06	1.18	1.24	1.21	1.05	1.09	0.92	0.34	0.30	0.23	0.20	0.20	0.18	0.20	0.19
SMOKE SPOT (COH)											0.1									
SO^2, (PPHM)	0.975		0.95		0.80			0.825		0.65	1.225	0.745	0.75		0.665		0.96	0.80		0.825

TIME (mid sample)	1815	1825	1835	1845	1855	1905	1915	1925	1935	1945	1955	2005	2015	2025	2035	2045	2055	2105	2115	2125	2135
TEMPERATURE (°F)																					
500 feet	81.75	82	81.75	81.5	81	80.5	81	81	80.5	80.5	80	80	80	79	79.5	79	78	78.25	78.5	78	78
170 feet	83.25	83.5	83.5	83.5	82.5	82	82	82.5	81.5	81.5	81.5	81.5	81.5	80.75	80.75	80.75	79.75	79.75	79.75	79	79
70 feet	83.75	84	84	84	83	83	83	83	82	82	82	82	82	81	81	81	80	80	80	79	79
RELATIVE HUMIDITY (%)																					
500 feet	50			52.4			52.5			57.2			58.3			58.7			61		
170 feet		50.9			52.9			53.2			57.9			59			60.1			57.5	
70 feet			51.6			51.1			56.7			58.8			59.2			61.1			63
BAROMETRIC PRESSURE (mm.Hg)																					
500 feet	730.94			730.94			730.83			730.83			730.83			730.83			730.83		
170 feet		739.94			739.94			739.83			739.83			739.83			739.83			739.83	
70 feet			743.35			743.25			743.25			743.25			743.25			743.25			743.25
WIND (direction-knots)																					
500 feet			SSE 9			SSE 9			SSE 9			SE 9			SE 9			SSE 9			SE 12
170 feet			SSE 7			SE 7			SE 7			SE 8			SE 7			SE 7			SE 6
70 feet			SE 8			SE 7			SE 8			SE 8			SE 6			ESE 6			SE 7
DIRECT RADIATION (CAL / CM²-MIN.)	0.45	0.41	0.30	0.35	0.37	0.28	0.26	0.23	0.19	0.14	0.10	0.06	0.05	0.02	0.01	0.006					
SMOKE SPOT (COH)			0.3												0.5						
SO^2, (PPHM)		1.0	0.9		0.825					1.325		1.5	1.445	1.75	1.385		1.65	1.325	1.5	1.225	

Table B-VII Micrometeorological data for the period 1455-2135, 19 July 1967.

TIME(mid samples)	2145	2155	2205	2215	2225	2235	2245	2255	2305	2315	2325	2335	2345	2355	0005	0015	0025	0035	0045	0055	0105
TEMPERATURE (°F)																					
500 feet	78.5	78	78	78	77	77	76.5	77.5	78	79	78.5	78	78.5	77.5	77.5	78	78	78.5	78.5	78	77.5
170 feet	79	78	78	78	77	76.5	76	76	76	76	76	75	75	75	75	75	75	75	75	75	74.5
70 feet	79	78	78	78	77	76.5	76	76	76	76	76	75	75	75	75	75	75	75	75	75	74.5
RELATIVE HUMIDITY (%)																					
500 feet	60.9			61.3			63.4			55.8			56.5			58.2			57.5		
170 feet		61.2			65.9			68.3			68.2			69.8			68.6			67.1	
70 feet			64			67.2			67.6			70.1			68.7			68.2			67.7
BAROMETRIC PRESSURE (mm. Hg)																					
500 feet	730.83			731.14			731.14			731.25			731.25			731.46			731.46		
170 feet		739.83			740.14			741.14			740.25			740.25			740.45			740.45	
70 feet			743.56			743.56			743.66			743.66			743.87			743.87			743.87
WIND (direction-knots)																					
500 feet			SSE 15			SSE 14			SSW 11			SSW 10			SSW 9			SSW 9			SSW 11
170 feet			SE 9			SE 9			SSE 8			SSE 7			SSE 8			SSE 7			SSE 8
70 feet			SE 6			ESE 6			SE 9			SE 7			SE 6			SE 6			SE 7
DIRECT RADIATION (CAL / CM^2-MIN.)																					
SMOKE SPOT (COH)																					
SO^2, (PPHM)								1.2			1.125				1.05			1.025			

TIME(mid samples)	0115	0125	0135	0145	0155	0205	0215	0225	0235	0245	0255	0305	0315	0325	0335	0345	0355	0405	0415	0425	0435
TEMPERATURE (°F)																					
500 feet	77.5	77.5	77.5	77.75	77.5	76.5	75.75	76	76	77	73	73.5	73.5	73.75	74	73.5	73.5	73.75	73.5	73.5	74.25
170 feet	74.5	74	74	74.5	72.75	73	73	72.5	72	72	72.5	73	73	73	72.5	72	72	71	71	71	71
70 feet	74.5	74	74	74	72.5	72.5	72.5	72	72	72	72	72	72	72	72	72	72	71	71	71	71
RELATIVE HUMIDITY (%)																					
500 feet	57.3			57.6			62.1			57.9			63.7			65.4			66.7		
170 feet		69.9			72.2			72.4			72.4			69.9			73.2			76.1	
70 feet			68.9			70.5			72.3			72.6			72			74.7			75.1
BAROMETRIC PRESSURE (mm. Hg)																					
500 feet	731.46			731.46			731.35			731.35			731.30			731.30			731.30		
170 feet		69.9			740.45			740.35			740.35			740.30			740.30			740.30	
70 feet			743.87			743.76			743.76			743.71			743.71			743.71			743.71
WIND (direction-knots)																					
500 feet			SW 16			SW 17			SW 16			SW 15			SW 13			WSW 12			WSW 13
170 feet			SSE 7			SSE 6			SSE 6			SSW 6			SSE 5			SSE 5			SSE 5
70 feet			SE 6			SSE 4			SE 6			SSE 4			SSE 4			SE 4			SE 5
DIRECT RADIATION (CAL / CM^2-MIN.)																					
SMOKE SPOT (COH)								0.4												0.4	
SO^2,(PPHM)	0.95			0.825				0.825				0.80		0.75		0.825		0.80		0.825	

Table B-VIII Micrometeorological data for the periods 2145-2355, 19 July 1967 and 0005-0435, 20 July 1967.

TIME(mid sample)	0445	0455	0505	0515	0525	0535	0545	0555	0605	0615	0625	0635	0645	0655	0705	0715	0725	0735	0745	0755	0805
TEMPERATURE (°F)																					
500 feet	75	75.5	70.5	74.5	73.5	74	75	75.5	71.5	71.5	71.5	71	70	70	71	71.5	72.5	71.25	70.5	70	70.5
170 feet	71	71	70.5	71	71	71	71	71	70	69.5	69.5	69.5	69.5	69.5	69.75	69.5	69.5	69.5	69.5	69.75	71.5
70 feet	71	71	70	70	71	71	71	71	69.5	69.5	69.5	69.5	69.5	69.5	70	70	70	70	70.25	70.5	72
RELATIVE HUMIDITY (%)																					
500 feet	64.9			65.8			65.4			74.7			79.6			77.2			82.4		
170 feet		76.4			76.9			77.7			82.1			82.3			85.2			87.5	
70 feet			77.7			72.4			79.1			81.3			79.1			80.8			80.8
BAROMETRIC PRESSURE (mm. Hg)																					
500 feet	731.30			731.35			731.35			731.66			744.07			731.77			731.77		
170 feet		740.30			740.30			740.35			740.66			740.66			740.76			740.76	
70 feet			743.76			743.71			744.07			744.07			744.18			744.18			744.23
WIND (direction-knots)																					
500 feet			WSW 13			WSW 12			WSW 12			WSW 13			WNW 13			WNW 11			WSW 9
170 feet			SSW 7			SSE 7			SSE 7			SSE 6			SSE 6			SSW 5			SW 5
70 feet			SSE 6			SSE 6			SSE 5			SSE 5			SSE 4			SSW 3			SSW 5
DIRECT RADIATION (CAL / CM^2-MIN.)							0.01	0.02	0.04	0.07	0.08	0.10	0.14	0.16	0.20	0.23	0.26	0.28	0.33	0.39	0.44
SMOKE SPOT (COH)												0.5									
SO^2, (PPHM)	0.70		0.70		0.70		0.80		0.75		0.825			0.725		0.775					0.9

TIME(mid sample)	0815	0825	0835	0845	0855	0905	0915	0925	1755	1805	1815	1825	1835	1845	1855	1905	1915	1925	1935	1945
TEMPERATURE (°F)																				
500 feet	71.5	72.5	72.5	74	73.1	73.5	74.5	75	80	79.5	81	80.75	80.5	81.25	81.5	82	81.5	81.5	81	81.25
170 feet	72.25	73	74	75	75	75	76	76.5	79.5	79.5	80	81.5	81.5	82.5	83	83.5	83	82.75	82.25	83
70 feet	73	74	75	76	76	76	77	77.5	80	79.5	80	81.5	81.5	83	83.5	84	83.5	83.5	83	83
RELATIVE HUMIDITY (%)																				
500 feet	82.3			76			79.6		48.7			52.9			51.1			52.3		
170 feet		77.9			75.2			74.1		54.9			53.1			48.8			51.5	
70 feet			70.8			72					56.3			50.7			50.2			52.5
BAROMETRIC PRESSURE (mm.Hg)																				
500 feet	731.82			731.82			731.82		731.14			731.14			730.83			730.83		
170 feet		740.82			740.82			740.82		740.14			740.14			739.83			739.83	
70 feet			744.23			744.23					743.56			743.56			743.25			743.25
WIND (direction-knots)																				
500 feet			WSW 7			WSW 6			NE 10	NE 4			WNW 2			SE 5		SE 7		
170 feet			SW 3			SW 3			SW 14	SSW 14			SSW 12			SSW 14		SSW 14		
70 feet			SSW 3			SSW 4			NE 6	NE 6			NNW 2			ESE 4		SE 6		
DIRECT RADIATION (CAL / CM^2-MIN.)	0.47	0.51	0.56	0.60	0.63	0.67	0.71	0.75	0.77											
SMOKE SPOT (COH)			0.4										0.4							
SO^2, (PPHM)		0.775		1.05	1.1	1.075	1.075	1.075	1.05											

Table B-IX   Micrometeorological data for the periods 0445-0925 and 1755-1945, 20 July 1967.

TIME (mid sample)	1010	1020	1030	1040	1050	1100	1110	1120	1130	1140	1150	1200	1210	1220	1230	1240	1250	1300	1310
TEMPERATURE (°F)																			
500 feet	65	66.5	66.25	66	66.5	66.75	67	66.75	67.25	67	67.5	67.75	68.75	68.5	69	69.5	69.25	69.25	69
170 feet	66.5	68	68	68	69	68.75	68.75	68.75	69.25	69.5	70	69.5	70.75	71	71	70.75	70.5	71	71.25
70 feet	68	69	69	69	70	70	70	70	70.5	70.5	71	71	72	72	72	72	72	72	72
RELATIVE HUMIDITY (%)																			
500 feet		49.5			50.9			51.5			49.4			50.5			50.3		
170 feet			47.9			49.5			48.8			48.2			52.1			49.6	
70 feet	47.4			45.2			46.5			46.7			44.9			46.1			47.5
BAROMETRIC PRESSURE (mm. Hg)																			
500 feet		729.2			729.2			729.2			729.2			729.1			729.1		
170 feet			738.2			738.2			738.2			738.1			738.1			738.1	
70 feet	741.6			741.6			741.6			741.6			741.5			741.5			741.5
WIND (direction-knots)																			
500 feet		NZ 7			NNE 6			ENE 7		ENE 8				NE 7			NNE 6		
170 feet		NE 3			NE 5			NE 4		NE 4				NE 3			NE 2		
70 feet		NE 6			NE 6			NNW 6		ENE 9				NE 8			NE 6		
DIRECT RADIATION (CAL / CM^2-MIN.)	0.94	1.03	1.06	1.11	1.07	1.15	1.13	1.18	1.15	1.19	1.23	1.24	1.29	1.27	1.32	1.29	1.27	1.28	1.28
SMOKE SPOT (COH)			0.25												0.15				
SO^2, (PPHM.)	0.575	0.45	0.375	0.30		0.275		0.275	0.25		0.40	0.25	0.20		0.15	0.20	0.25	0.25	

TIME (mid sample)	1320	1330	1340	1350	1400	1410	1420	1430	1440	1450	1500	1510	1520	1530	1540	1550	1600	1610
TEMPERATURE (°F)																		
500 feet	69	69	69	68.5	68.5	70.0	70.0	70	70	70.5	71	71	70.5	70.5	70.75	70.5	71	71
170 feet	71	71	71	71	71.5	72.5	72	72	72.25	72.25	72.75	72.5	72	72	72.5	72.5	73.25	73.25
70 feet	72	72	72	72	72	73	73	73	73	73.5	74	74	73	73	74	74	74	74
RELATIVE HUMIDITY (%)																		
500 feet	51.6			48.9			46.4			43.4			44.8			46.5		
170 feet		50.9			44.7			44.0			40.5			42.8			41.8	
70 feet			46.3			43.0			43.7			39.7			40.5			39.7
BAROMETRIC PRESSURE (mm. Hg)																		
500 feet	729.1			729.1			728.9			728.9			728.8			728.8		
170 feet		738.1			737.9			737.9			737.8			737.8			737.7	
70 feet			741.5			741.3			741.3			741.2			741.2			741.1
WIND (direction-knots)																		
500 feet	NNW 6			NNE 6			NNE 5			NNE 6			NE 6			NE 6		
170 feet	NE 2			NE 2			NE 2			NE 2			NE 2			NE 2		
70 feet	NE 6			NNE 5			NNE 5			NE 6			ENE 6			ENE 6		
DIRECT RADIATION (CAL / CM^2-MIN.)	1.24	1.22	1.26	1.27	1.25	1.23	1.21	1.07	1.17	1.10	1.16	1.12	1.01	1.05	1.04	1.01	0.97	0.93
SMOKE SPOT (COH)								0.15										
SO^2, (PPHM.)	0.45	0.20	0.10			0.075		0.15	0.175	0.175	0.175	0.20	0.175	0.175	0.20	0.20	0.215	

Table B-X Micrometeorological data for the period 1010-1610, 27 July 1967.

TIME (mid sample)	1620	1630	1640	1650	1700	1710	1720
TEMPERATURE (°F)							
500 feet	71.5	71.5	71.5	71.25	71	71.5	72.5
170 feet	73	73.25	73.5	78.5	73	73.5	74.25
70 feet	74	74	74.5	74.5	74	74.5	75
RELATIVE HUMIDITY (%)							
500 feet	40.7			41.7			40.1
170 feet		39.4			41.8		
70 feet			38.3			38.3	
BAROMETRIC PRESSURE (mm.Hg)							
500 feet	728.7			728.7			728.7
170 feet		737.7			737.7		
70 feet			741.1			741.1	
WIND (direction-knots)							
500 feet	NNE 5			NNE 5			NE 5
170 feet	NNW 4			WSW 5			WNW 5
70 feet	NNE 6			NNE 5			NE 5
DIRECT RADIATION (CAL / CM^2-MIN.)	0.90	0.88	0.84	0.78	0.75	0.70	0.6
SMOKE SPOT (COH)		0.25					
SO^2 , (PPHM.)	0.20	0.225	0.175	0.20	0.20	0.25	

Table B-XI Micrometeorological data for the period 1620-1720, 27 July 1967.